

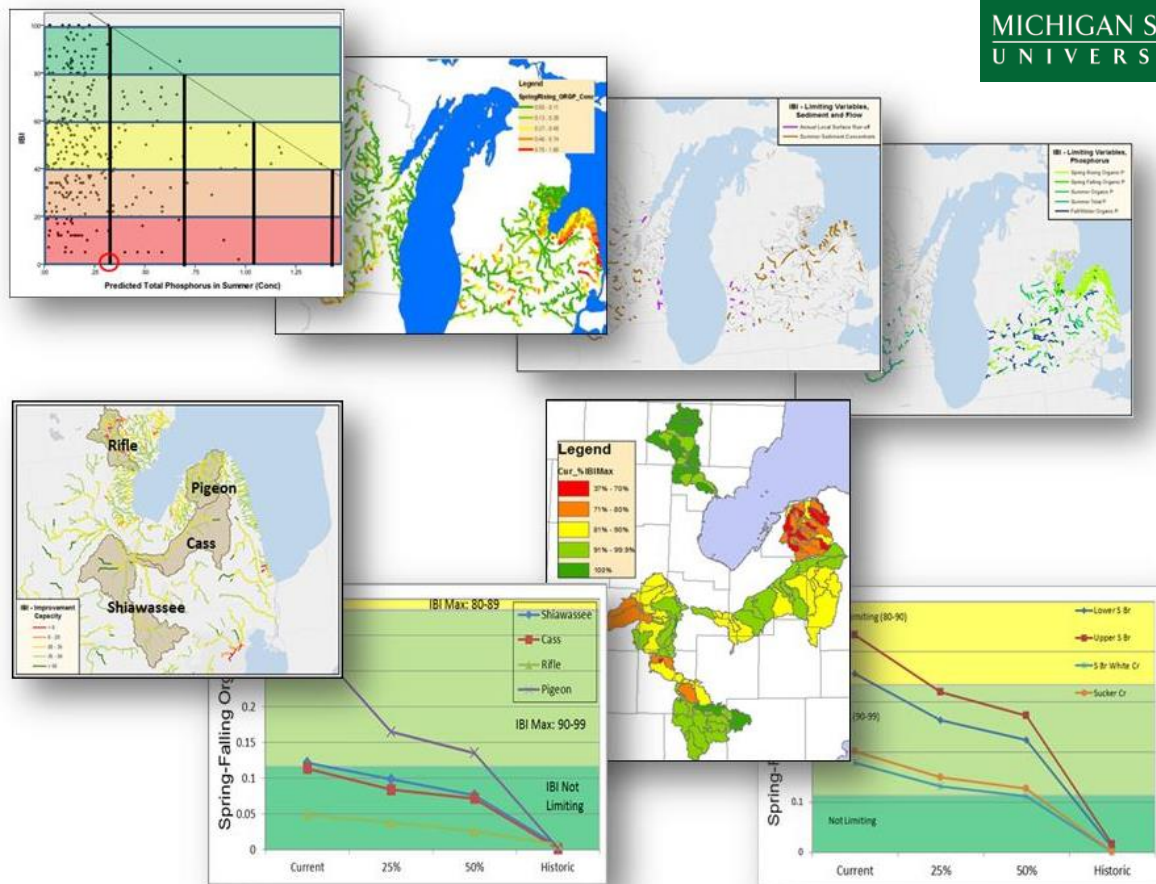


Conservation Effects Assessment Project

Great Lakes Phase 2 Final Report

Assessing the Costs and Benefits of Conservation Practices to
Restoring Biological Integrity in Agricultural Watersheds

The Nature Conservancy
in collaboration with Michigan State University



United States Department of Agriculture
Natural Resource Conservation Service
Conservation Effects Assessment Project:

*A Multi-agency Effort to Quantify the Environmental Effects
of Conservation Practices and Programs*

Assessing the Ability of Conservation Practices to Restore Biological Communities in Agricultural Watersheds

FINAL REPORT

31 March 2013

Scott P. Sowa, Principal Investigator
Matthew Herbert, Lead Ecological Modeler
Kimberly R. Hall, Climate Analyses
Layla Cole, Data Management, Analysis and Modeling
Sagar Mysorekar, GIS Mapping and Modeling
Mary Fales, Partner Outreach and Engagement
Tia Bowe, GIS Mapping and Modeling
Gust Annis, GIS Mapping
Amirpouyan Nejadhashemi, SWAT Modeling
Lizhu Wang, Fish Community Data and Cooperator

The Nature Conservancy
Michigan Chapter
Lansing, MI 48906

Submitted by:
Scott P. Sowa and Matthew Herbert

Cooperative Agreement: 68-7482-11-501
(Great Lakes CEAP Project: Phase 2)

Suggested Citation:

¹Sowa, S. P., ¹M. Herbert, ¹K. R. Hall, ¹L. Cole, ¹S. Mysorekar, ¹M. Fales, ¹T. Bowe, ¹G. Annis, ²A. Nejadhashemi, and ³L. Wang. 2011. Assessing the Ability of Conservation Practices to Restore Biological Communities in Agricultural Watersheds. Final Report submitted to NRCS Conservation Effects Assessment Project. 69 pp.

¹ The Nature Conservancy

² Michigan State University, Department of Biosystems and Agricultural Engineering

³ International Joint Commission

TABLE OF CONTENTS

List of Tables.....	iv
List of Figures.....	v
Executive Summary.....	vi
Acknowledgements.....	vii
General Introduction.....	1
Objective 1 Introduction.....	4
Objective 1: Methods.....	7
Objective 1 Results.....	14
Objective 2 Introduction.....	52
Objective 2: Methods and Results.....	53
Overall Discussion.....	56
Conclusions.....	60
Literature Cited.....	61

LIST OF TABLES

Table 1.	Key water quality variables identified in Phase I of the project.....	10
Table 2.	Potential criteria for total phosphorous concentrations for Ohio.....	12
Table 3.	Examples of % Maximum IBI score calculations.....	13
Table 4.	List of Advisory Panel Members.....	15
Table 5.	Frequency of NRCS conservation practices implemented from 1999-2009.....	18
Table 6.	Summary of ecological benefits of NRCS conservation practices.....	19
Table 7.	Ten conservation practices selected for modeling scenarios.....	20
Table 8.	Average percent (%) maximum attainable IBI across subwatersheds.....	26
Table 9.	Average percent (%) maximum attainable % Intolerant across subwatersheds.....	35
Table 10.	Proportional changes in loads and concentrations for selected variables from SWAT models for climate change projections.....	42
Table 11.	List of core team members for Western Lake Erie CEAP project.....	54

LIST OF FIGURES

Figure 1.	Performance pyramid for indicators.....	3
Figure 2.	Study area for phase 2 of the Great Lakes CEAP project.....	6
Figure 3.	Wedge plot example from phase 1.....	11
Figure 4.	Location of the four priority watersheds.....	16
Figure 5.	NRCS conservation practices in the four priority subwatersheds.....	17
Figure 6.	Dose-response curves for IBI scores at watershed outlets.....	23
Figure 7.	Dose-response curve example for subwatersheds.....	24
Figure 8.	Maximum attainable IBI based on natural variables and non-agricultural threats.....	25
Figure 9.	Percent maximum attainable IBI score for conservation practice scenarios	27
Figure 10.	Change in the percent maximum attainable IBI score across conservation practice scenarios.....	28
Figure 11.	Most limiting water quality variable to IBI scores for conservation practice scenarios.....	29
Figure 12.	Number of limiting water quality variables to IBI scores for conservation practice scenarios.....	30
Figure 13.	Change in the number of limiting water quality variables to IBI scores across conservation practice scenarios.....	31
Figure 14.	Dose-response curves for % Intolerant at watershed outlets.....	33
Figure 15.	Maximum attainable % Intolerant based on natural variables and non-agricultural threats.....	34
Figure 16.	Percent maximum attainable % Intolerant score for conservation practice scenarios.....	36
Figure 17.	Change in the percent maximum attainable % Intolerant score across scenarios.....	37
Figure 18.	Number of limiting water quality variables to % Intolerant scores for conservation practice scenarios.....	38
Figure 19.	Change in the number of limiting water quality variables to % Intolerant scores across conservation practice scenarios.....	39
Figure 20.	Precipitation patterns for 2080 climate projections.....	41
Figure 21.	Dose-response curves for conservation practice and climate scenarios.....	43
Figure 22.	Estimated implementation costs for conservation practice scenarios.....	45
Figure 23.	Proportion of subwatersheds where water quality is limiting fish community health.....	45
Figure 24.	Focal subwatersheds for Cass River Watershed pilot project.....	51

EXECUTIVE SUMMARY

Agriculture, through its production of food, materials for clothing and shelter, and jobs, plays an important role in improving the quality of life for people across the United States, including those residing in the Great Lakes Region. Unfortunately, the collective benefits of agriculture can sometimes have associated costs, particularly with regard to alteration of aquatic ecosystems, which also influence people's quality of life and are also highly valued by society. Over the years farmers and state and federal governments have developed programs, policies, and funding mechanisms, like the Food Security Act of 1985 (aka the 1985 Farm Bill) to improve the sustainability and profitability of agriculture and to also reduce the impacts of agriculture on fish and wildlife habitat. In recent years there has been increased interest in a more thorough understanding and accounting of the benefits of these conservation practices to fish and wildlife. In response the Conservation Effects Assessment Project (CEAP) was initiated by the NRCS, Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES) to help better inform society of the likely benefits Farm Bill conservation program funding. Early CEAP investigations revealed that the cumulative benefits of NRCS conservation practices to aquatic communities is poorly understood and further scientific investigation is needed. The Great Lakes CEAP Project grew out of this realization and seeks to provide the science needed to assess and forecast benefits of NRCS conservation practices to stream fish communities to help advance *strategic* conservation of riverine ecosystems across agricultural regions of the Great Lakes.

Strategic conservation involves getting the right conservation practices to the right places in the *right amount* to achieve a *realistic* set of desired ecological and socioeconomic conditions. In an adaptive management framework strategic conservation should be guided by related sets of performance indicators and goals. Unfortunately, conservation efforts are often guided by resource input (e.g., funding) and conservation action goals (e.g., acres of practices), with little or no understanding of what ecological or socioeconomic benefits will result from those inputs or actions. Ideally, these input and action goals should be established based on *what is needed* to achieve a realistic set of desired ecological and socioeconomic conditions, which then poses the questions of "How much conservation is enough?" and "How much will it cost?" to achieve those conditions? This outcome driven approach requires both an understanding of the relations between ecological indicators and the ability to forecast the cumulative benefits and costs of various conservation scenarios, which were both addressed in our two phase project. Phase 1 of our project developed a unique approach of using the outputs from a fine resolution SWAT model to identify thresholds and ceilings for fish community metrics associated with several water quality and flow variables. The predictive capabilities of SWAT allowed us to then, in Phase 2, forecast the likely cumulative benefits and costs of potential future conservation practice scenarios, which are now being used by various partners to establish realistic goals and strategies to achieve them.

Our unique approach of linking ecological outcomes to conservation actions and associated costs provides decision makers with a wealth of information to answer important questions. However, even with this information in hand there are no easy answers. But this is really the essence of conservation...we are usually faced with difficult decisions that involve trade-offs among places and things we value. The information makes us face, rather than ignore, those tough decision. The results of our cost-benefit analyses clearly show how important downscaling is, because there is not a simple additive mathematical relationship between the costs to achieve unlimiting conditions for a larger watershed and the cost to achieve those same conditions for all tributary streams in that watershed. The question is really stream specific due to the unique natural and human disturbance

conditions in the watershed, which demonstrates why our approach and in particular the downscaling of the SWAT model is so important. If we had not downscaled our results to the subwatershed scale the results for the outlets might be interpreted that water quality in all streams of the Cass, Rifle and Shiawassee could be improved to the point that row-crop agriculture was no longer limiting the fish community, for “only” \$7.7M. Yet, the more detailed subwatershed cost-benefit analyses predict fish communities would still be limited in many of the subwatersheds under the 50% conservation scenario, which has an estimated overall estimated installation cost of around \$44M. We recognize that the Farm Bill is not the only source of restoration funds, but it is the largest funding source for restoration on agricultural lands. Under the 2008 Farm Bill the state of Michigan received a total of \$40,788,221. The total cost of our 50% conservation scenario for our four focal watersheds is over \$44M and even under this scenario the fish communities in several streams are predicted to still be limited. So, with those goals the scope of the problem, in terms of costs related to historical practice implementation, is predicted to be significantly greater than the resources that were available to Michigan under the 2008 Farm Bill. Through strategic placement practices we can reduce these costs by ~25% or more in some instances. Yet, even with such savings to achieve these ecological goals across Michigan or all agricultural lands will force the conservation and agricultural community, legislators, businesses, and the public to make some hard decisions to a) significantly increase the conservation provisions of the Farm Bill, b) think “outside the box” to develop new conservation practices or strategies, c) lower our ecological goals, or d) a combination of all three.

The Cass River Implementation Pilot Project and our other ongoing efforts with local partners in the Saginaw Bay watershed showcase how the results from our project can immediately influence targeting, outreach and implementation decisions and expectations. One of the most important and gratifying aspects of our project has been the help we received from local partners during the project and also their rapid acceptance and use of the results to guide their conservation efforts. This more than anything has been a testament to the importance of answering the ever present “How much is enough?” question in a way that forces us to answer several difficult questions related to setting related sets of realistic goals.

During Phase 1 of the Great Lakes CEAP project we identified several ways to improve the downscaled SWAT modeling and also the ecological modeling for identifying thresholds and ceilings. Fortunately, through our work in this project we were able develop and launch the Western Lake Erie Basin (WLEB) CEAP project, which is addressing almost all of these recommended improvements. Furthermore, the WLEB CEAP project serves another, equally important, purpose to foster the formal integration of the Wildlife and Cropland components of CEAP, which is occurring as a result of the unique modeling and assessment approach developed by the Great Lakes CEAP project. It is our hope that the combined results and benefits of the Great Lakes and WLEB CEAP projects will lead to both the desired operational integration of the Wildlife and Cropland components of CEAP and the continued expansion and use of our approach to other geographies. As the ongoing work with our partners clearly shows, the conservation and agricultural communities desire having the ability to establish realistic sets of related performance goals that provide a foundation for strategic, outcome-based, conservation.

ACKNOWLEDGEMENTS

We first want to thank to Charlie Rewa for his unwavering support of this project through the Wildlife Component of the NRCS CEAP. We also want to thank our Advisory Panel members who have been so valuable to this second phase of the project; Charlie Bauer, Patti Copes, Abigail Ertel, Dawn Hergott, Jim Hergot, Melissa Higbee, Mike Kelly, Jim Kratz, Lisha Ramsdell, Jeanette Renn, Steve Shine, and Tom Wert. We also want to thank our many local partners we are currently working with throughout Saginaw Bay and beyond. There are too many names to list here, but fortunately we were able to appropriately acknowledge them within the report. We also want to thank our key collaborators on this project who have contributed in many ways by providing critical input, review, and data needed to successfully complete this project. Specifically, we want to thank several individuals from Michigan State University, including Brad Wardynski from the Department of Biosystems and Agricultural Engineering, Jon Bartholic from the Institute of Water Research, Phanikumar Mantha and Chaopeng Shen from the Department of Civil and Environmental Engineering, and Dana Infante and Arthur Cooper from the Department of Fisheries and Wildlife. We would also like to thank Jana Stewart from the USGS Water Resource Division for providing critical datasets. Finally, we would like to thank Susan Wallace and George Wallace, of the USDA NRCS Resources Inventory and Assessment Division, for compiling the NRCS National Conservation Planning Database data sets used in this project. Additional financial support for TNC staff working on this project was provided by The Nature Conservancy's Great Lakes Fund for Partnership in Conservation Science and Economics.

General Introduction

Agriculture, through its production of food, materials for clothing and shelter, and jobs, plays an important role in improving the quality of life for people across the United States, including those residing in the Great Lakes Region. In economic terms alone the benefits of agriculture to the Great Lakes Region are immense. The 2007 Census of Agriculture reported that there were nearly 126,000 farms in the region and that the value of agricultural sales was about \$14.5 billion with about half of this total generated from crop production and the other half from livestock production. About 67 percent of the farms in the Great Lakes Region primarily raise crops, about 26 percent are primarily livestock operations, and the remaining 7 percent produce a mix of livestock and crops. The five Great Lakes also moderate the climate of coastal areas, improving production and creating microclimates that are ideal for specialty crops such as cherries, asparagus and wine grapes. These high-value specialty crops also lead to spin-off industries such as culinary festivals and beverage production that provide social benefits and further increase economic outputs and jobs related to recreation and tourism. Unfortunately, the collective benefits of agriculture can sometimes have associated costs, particularly with regard to alteration of aquatic ecosystems, which also influence people's quality of life and also highly valued by society and organizations like The Nature Conservancy (TNC).

The effects of agriculture on aquatic ecosystems and freshwater biodiversity have been extensively studied and documented. Studies have consistently shown that various practices associated with row-crop agriculture, including vegetative clearing, soil compaction, water withdrawal, channelization, and irrigation can significantly alter flow regimes, physical habitat, energy flow, water quality and the plant and animal biota (FISRWG 2001; Richter et al. 1997; Waters 1995). Major agricultural stressors include altered flow and thermal regimes and excess nutrients and sediments which affect 55% of the impaired waters in the United States (Allan 2004). Collectively these changes in habitat lead to corresponding changes in the biotic communities and many recent studies have revealed connections between increased nutrients, sediments, and pesticides with changes in biological measures of algae, invertebrate, and fish communities (Frey et al. 2011; Hambrook-Berkman et al. 2010; Wang et al. 2006; Heiskary and Markus 2003; Cuffney et al. 2000; Rankin et al. 1999). Over the years farmers and state and federal governments have developed programs, policies, and funding mechanisms, like the Food Security Act of 1985 (aka the 1985 Farm Bill) to improve the sustainability and profitability of agriculture and to also reduce the impacts of agriculture on fish and wildlife habitat.

Passage of the 1985 Farm Bill authorized billions of dollars (US\$17 billion in 2002) for private land conservation (Gray and Teels 2006). Originally, the Farm Bill set out to reduce soil erosion from highly erodible sites and attempted to limit excess food production by idling marginal croplands (Heard et al. 2000). Since then, the Farm Bill has evolved to administer, through the United States Department of Agriculture Natural Resource Conservation Service (NRCS), additional programs (e.g., Wetlands Reserve Program and Environmental Quality Incentives Program) intended to improve wildlife habitat and environmental conditions in agricultural landscapes (Burger Jr. et al. 2006; Gray and Teels 2006; Heard et al. 2000). The majority of NRCS conservation practices do not directly target freshwater biological communities, but rather are intended to indirectly benefit these communities by improving water quality and hydrology. However, in recent years there has been increased interest in a more thorough understanding and accounting of the benefits of

conservation practices to fish and wildlife, particularly in response to the significant increase in funding for conservation programs that was authorized under the 2002 Farm Bill. In response the Conservation Effects Assessment Project (CEAP) was initiated by the NRCS, Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES) to help better inform society of the likely benefits Farm Bill conservation program funding (Mausbach and Dedrick 2004). The original goals of CEAP were to establish the scientific understanding of the effects of conservation practices at the watershed scale and to estimate conservation impacts and benefits for reporting at national and regional levels.

CEAP projects have mostly investigated the response of terrestrial ecosystems or species to a subset of NRCS practices (e.g., Burger Jr. et al. 2006a; Heard et al. 2000), or have targeted water quality issues by using hydrological models to assess sediment and contaminant loading in streams after conservation practice implementation (Westra et al. 2005). However, a pilot study concluded that NRCS conservation practices do have the potential to improve stream habitat conditions for a variety of aquatic species by targeting specific conservation practices to specific locations using modeled species distributions within a geographic information system (GIS) (Comer et al. 2007). The authors of this pilot study also noted that the specific or cumulative benefits of NRCS conservation practices to aquatic communities was poorly understood and further scientific investigation through a combination of a) localized, field based, watershed studies and b) geographically extensive, associative, modeling studies were needed. The Great Lakes CEAP Project grew out of this realization and seeks to provide the science needed to assess and forecast the benefits of NRCS conservation practices to stream fish communities to help advance *strategic conservation* of riverine ecosystems across the agricultural regions of the southern Great Lakes. Strategic conservation involves getting the right conservation practices to the right places in the *right amount* to achieve a *realistic* set of desired ecological and socioeconomic conditions. In an adaptive management framework strategic conservation should be guided by related sets of performance indicators and goals (Figure 1). Unfortunately, conservation efforts are all too often guided by resource input (e.g., funding) and conservation action goals (e.g., acres of practices), with little or no understanding of what ecological or socioeconomic benefits will result from those inputs or actions. Ideally, these input and action goals should be established based on *what is needed* to achieve a realistic set of desired ecological and socioeconomic conditions, which then poses the question of “How much conservation is enough?” and “How much will it cost?” to achieve those conditions? This outcome driven approach requires both an understanding of the relations between indicators in 3 or more levels of the performance pyramid and the ability to forecast the cumulative benefits of different amounts of inputs and actions, which were both addressed in our two phase project (Figure 1).

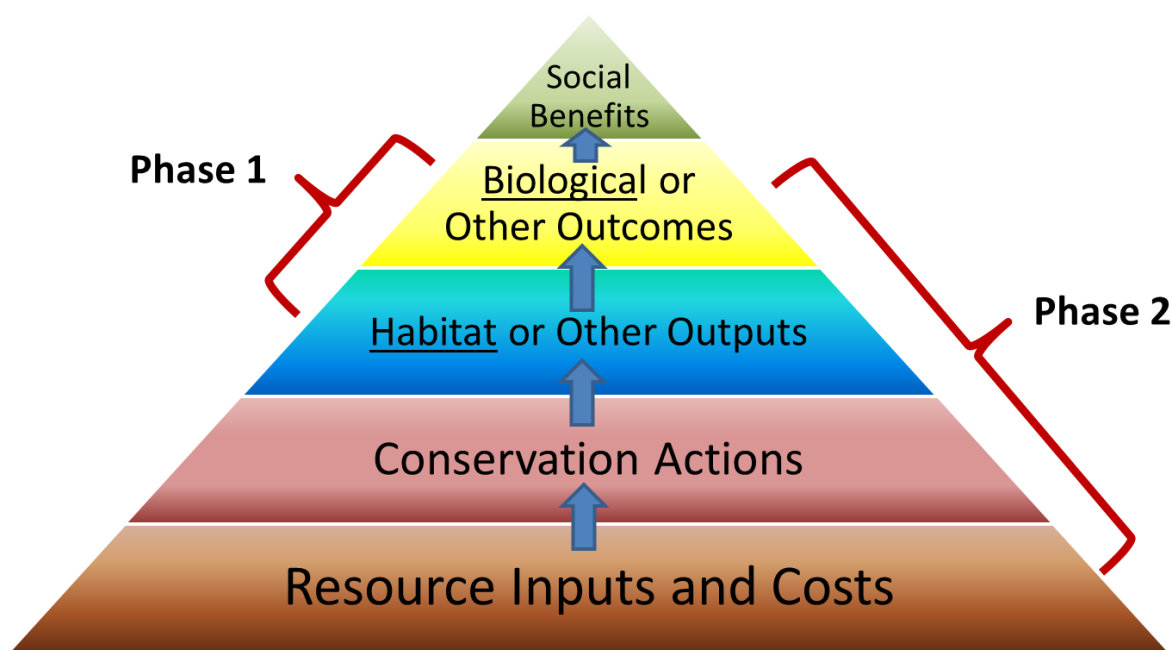


Figure 1. Performance pyramid showing the five levels that each have distinct sets, but interrelated, indicators. The role of science, like our project, is to reveal the relations between the indicators across these levels so that resource managers and society can use this information to establish related sets of realistic goals to guide strategic conservation. Phase 1 of our project used a unique approach of revealing relations between habitat and biological indicators that allowed us to forecast cumulative benefits of different amounts of conservation actions and costs in Phase 2, which are now being used by various partners to establish realistic goals and strategies to achieve them.

The overall goal of the Great Lakes CEAP Project was to provide resource managers with the information and tools needed to establish realistic sets of related performance goals to guide strategic conservation on row-crop agricultural lands. The project occurred in two phases. Phase 1 of our project, used a unique approach of revealing relations between habitat and biological indicators that allowed us to forecast cumulative benefits of different amounts of conservation actions and costs in Phase 2, which is the focus of this report.

Phase 1 of our overall project was thoroughly covered in earlier complimentary report (Sowa et al. 2011). However, a brief overview of this work that provided the foundation for Phase 2 is necessary as it provides a necessary context for fully understanding the content of this current report. So, to provide this context we briefly outline Phase 1 here. During Phase 1 we developed predictive relationships between two fish community metrics and three sets of predictive variables for 345 streams across the agricultural regions of southern Michigan and Wisconsin. Two of these three sets of predictor variables; a) natural physiographic watershed variables (e.g., soils, drainage area) and b) non-target watershed disturbance variables (e.g., percent impervious surface, dam density, etc.) provided a critical context our third set of predictors, which our primary focus in order to help inform strategic conservation on row-crop agricultural lands. This last set of predictor variables included a large number of instream water quality and flow metrics derived from a fine-resolution Soil and Water Assessment Tool (SWAT) model that predicted the values for these variables under current conditions for all 345 streams. From all of these relations we identified thresholds and ceilings for the fish community metrics under specific watershed and habitat conditions. We were then able to use these thresholds and ceiling relations, in conjunction with

SWAT, to predict and map (under current conditions) five key pieces of information for all 345 streams;

1. the inherent natural ceilings for each fish community metric
2. where the fish community metrics were likely limited by non-target disturbances
3. where the fish community metrics were likely limited by water quality and flow alterations related to row-crop agriculture (i.e., our target disturbances)
4. which water quality and flow variables were likely most limiting and their relative sequence of limitation to the fish community, and
5. the expected maximum value (ceiling) for each fish community metric under current conditions.

Phase 2 of our project consists of two related but very different objectives.

Objective 1: Work with NRCS and other key partners to assess the ecological benefits and costs of future conservation scenarios within select priority watersheds of the Saginaw Bay watershed and use the resulting information to set realistic performance goals and guide strategic conservation for achieving them.

Objective 2: Help foster integration of the Wildlife and Cropland components of CEAP through the modeling and assessment process established by the Great Lakes CEAP project.

The purpose of our first objective was to: 1) develop a process where we could establish relations between water quality, biological communities, and conservation practices to help to set meaningful ecological and related performance goals to guide strategic conservation and 2) engage a variety of agricultural stakeholders to determine whether this process of setting goals was readily accepted and the resulting information would be used. The purpose of our second objective was to help advance the integration of the Wildlife and Cropland components of CEAP so that future regional assessments could move beyond water quality endpoints and include biological endpoints. Lastly the combined purpose of both objectives was to help improve our approach and help expand it to other geographies to foster outcome-based strategic conservation in those watersheds regions as well.

Objective 1 Introduction

The establishment of meaningful sets of performance goals to guide strategic conservation in agricultural watersheds has eluded the conservation community for several reasons. First, until recently we have not had the data needed to establish relations among biological endpoints, water quality, and conservation practices. Many studies have identified and evaluated relationships between water quality and biota (Rankin et al. 1999; Wang et al. 2006; Weigel and Robertson 2007. Miltner 2010; Dodds et al 2010;). However, none have been able to establish relations with conservation practices in a manner that allows us to assess cumulative costs and benefits in a spatially explicit and comprehensive way at multiple spatial scales across large geographic regions. To address this need we set out to develop a unique approach of relating fish community metrics to instream water quality and flow conditions predicted by SWAT. This approach is a compliment to and expands upon this large body of existing work. Our intent was to develop an approach expands on these previous efforts by further linking ecological conditions to conservation actions and costs.

By establishing relations across more levels of the performance pyramid we would be able to assess ecological benefits and costs in a comprehensive manner across large regions and at different spatial grains. These additional sets of relations would allow us to answer the ever present and complex “How Much is Enough?” question from many perspectives (e.g., ecological and economic) which is critical to setting realistic sets of performance goals.

Even if we successfully develop a process of setting realistic performance goals that are ecologically based and provide a foundation for strategic, outcome-based, conservation there is no guarantee it will be accepted and used. To help address this issue we worked with local partners on both the development of the process and its application to real world problems. This partner focused aspect of objective 1 is critical because it helps evaluate both the utility and acceptance of the resulting body of work with local partners. We firmly believe that if local partners do not understand, accept or use the results of this work then our ability to expand this work to other geographies and get this work supported by state, regional and national decision makers is virtually impossible.

A series of nine interrelated tasks, listed below, were established to accomplish objective 1. For this section of the report we present the methods and results for each of these tasks separately after a brief description of the study area for this objective.

Objective 1 Major Tasks

- 1a. Establish a Saginaw Bay advisory panel
- 1b. Quantify the amount (percent area, densities, or length) of all NRCS conservation practices within the local catchment and overall watershed of all stream reaches containing fish community collections within the Saginaw Bay drainage and larger regional project area.
- 1c. Use the information from task 1b to help select 10-15 NRCS conservation practices, based on prevalence, to ensure we develop realistic future conservation scenarios.
- 1d. Select priority watersheds for generating future conservation scenarios
- 1e. Within each selected subwatershed, use SWAT to model changes in physical, chemical, and biological conditions associated with different future conservation scenarios relative to current and historic conditions.
- 1f. Generate cost and time estimates for each scenario.
- 1g. Work with the Advisory Panel to compare and contrast the conservation scenarios.
- 1h. Use selected scenarios to develop more specific blueprints and schedules of conservation action.
- 1i. Work through the Advisory Panel to develop appropriate outreach and innovative solutions for carrying out the recommendations from task 1h.

Phase 2 Objective 1 Study Area

Our Phase 1 (Sowa et al. 2011) provides a detailed description of the overall Great Lakes CEAP project study area. Saginaw Bay was selected as the focal geography for Phase 2 of our project for several reasons. First, there are several stream systems within the region that are important for biodiversity conservation (TNC 2001). Saginaw Bay also maintains important biodiversity conservation elements and is important to the overall health of Lake

Huron (TNC 2000, TNC 2001, Liskauskas et al. 2007, Franks-Taylor et al. 2010). In addition, while agriculture is also a major contributor to pollution in the region (He and DeMarchi 2010). There is also significant landscape diversity across the region (Johnson et al. 1997), which provided the necessary heterogeneity for comparing outcomes of the conservation scenarios across a variety of landscape/watershed conditions (Figure 2). Most importantly Saginaw Bay was selected because of the large interest and investments in conservation on row-crop agricultural lands and the many well-established partnerships in the watershed, like the Saginaw Bay Watershed Initiative Network.

http://www.saginawbaywin.org/win_overview/

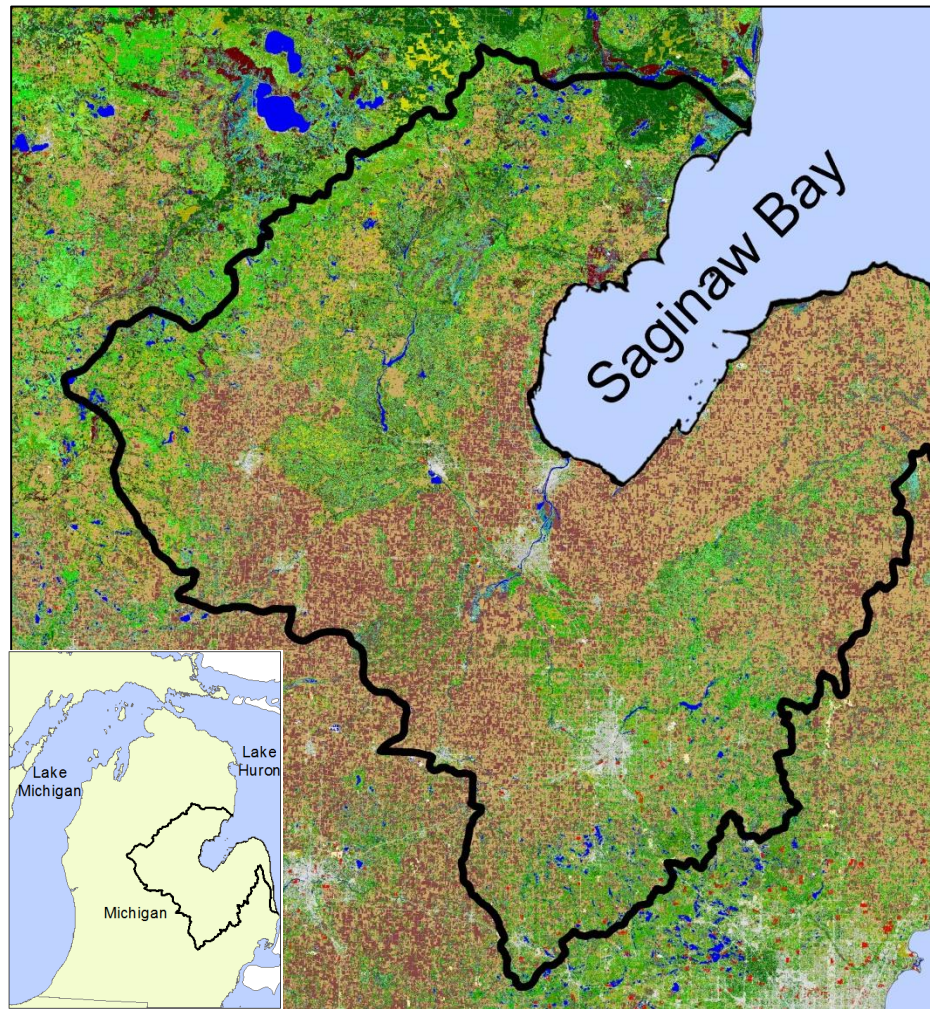


Figure 2. Map showing the overall Saginaw Bay basin where Phase 2 of the Great Lakes CEAP project was focused. Map colors correspond with land use with agricultural lands in brown, urban lands in grey, and natural land cover in green.

Objective 1 Methods For Each Task

1a. *Establish a Saginaw Bay advisory panel*

We identified several Saginaw Bay regional experts on agriculture or non-point source pollution. We also identified key local experts in implementing conservation practices within each of the focal watersheds. These individuals were invited to participate as an advisory panel for the project and were subsequently engaged at various points during the project. Engagement was to ensure that key decisions were informed by local expertise and to ensure that regional experts were familiar with the project to promote future collaboration.

1b. *Select watersheds for generating future conservation scenarios*

To determine which watersheds to focus on for conservation practice scenarios, we sought input from our Advisory Panel. We wanted the focal watersheds to be of high priority for conservation within the region, to increase the likelihood that the conservation community would be interested in using the results to guide their conservation decisions. In addition, we wanted the selected set of watersheds to represent a gradient of agricultural intensity so that we could evaluate conservation practice benefits across that gradient. That is, we wanted to be able to answer “How much conservation is enough (and How much would it cost?) to achieve a given level of ecological benefit in watersheds with a low, medium and high density of row-crop agriculture.?” Finally, we considered which rivers were identified as priority biodiversity areas through The Nature Conservancy’s ecoregional planning (TNC 2001).

1c. *Quantify the amount of all NRCS conservation practices implemented within the local catchment and overall watershed of all stream reaches containing fish community collections within the Saginaw Bay drainage and larger project area.*

The purpose of this task was to help guide the selection of practices for use in hypothetical future conservation scenarios. The purpose of these scenarios was to assess the ecological benefits and costs of significantly increased densities of BMPs. Since there are an infinite number of conservation scenarios for a given watershed we had to establish some meaningful baseline scenario from which to build upon. The project team and Advisory Panel determined that the historical densities of practices were the only meaningful standard for assessing the added ecological benefits and costs of increased BMP densities. The rationale behind this decision was the realization that the densities of practices that get implemented on the landscape are influenced by many factors, ranging from appropriateness for the cropping system to cost share ratios to farmer perceptions (Prokopy et al. 2008; Reimer et al. 2012). Consequently, if we wanted the future scenarios to be realistic we should “let history be the guide” and come up with a historical baseline. Furthermore, our Advisory Panel suggested that we should quantify historic practice densities for our selected watersheds rather than the larger Phase 1 project area or even the Saginaw Bay watershed, which we did.

To calculate historic BMP densities we used the 2010 USDA NRCS National Conservation Practice (NCP) database (USDA 2010) which contains practices that were

installed through from 1999-2009 through NRCS cost share programs. We quantified practices both with and without duplicate records. We did this because sometimes practices that have short term contracts, like 3 years, are in the practice database multiple times for the exact same location. Including these duplicate records artificially inflates practice densities. However, sometimes the benefit of a practice to improving water quality or flows is dependent upon how long that practice is actually applied. So we decided to also quantify practices with duplicate records to indirectly get at the extent of time a practice was applied since the actual time period is not included in the database.

- 1d. *Use the information from task 1b to help select 10-15 NRCS conservation practices to ensure we develop realistic future conservation scenarios.*

Using calculations from Task 1b, we evaluated the frequency and density of conservation practices within our four selected subwatersheds to help determine which practices should be used in future conservation scenarios. However, practices were eliminated from these analyses if they were not applicable to row-crop agriculture or if their benefits were not relevant to improvements in nutrients, sediment or streamflow. The relevancy of practices to these three major habitat attributes were based on an existing analysis by Fore (2012), who conducted a thorough review of NRCS Conservation Practice Standards (http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/?cid=nrcs143_026849), and in consultation with our Advisory Panel. Those practices meeting the above criteria that were implemented at the highest density/frequency were identified as a proposed list of practices to be included in the future conservation scenarios. Finally, we consulted with Dr. Amirpouyan Nejadhashemi (Department of Biosystems and Agricultural Engineering, Michigan State University), who led the SWAT modeling process for the future conservation scenarios, to assess the reliability and feasibility of modeling the likely benefits of each practice in SWAT.

- 1e. *Within each selected subwatershed, use SWAT to model changes in physical, chemical, and biological conditions associated with different future conservation scenarios relative to current and historic conditions.*

We worked with the Advisory Panel to establish a set of conservation scenarios that would provide useful dose-response relationships between increased BMP densities and predicted improvements in seasonal and annual water quality and flow and also fish community metrics. Our focus of this process was developing conservation scenarios that would complement two “bounding” sets of conditions, between current and historic that had already been modeled by SWAT in Phase 1 of the project. The Advisory Panel understood the need for using the current conditions in the dose-response curves; however, some were concerned about using historic conditions, which represented natural land cover (see Sowa et al. 2011 for methods and results of historic land cover SWAT models). When it was explained that we had a limited number of conservation scenarios that could be run and we needed to maximize the information gained from these dose-response analyses the panel agreed that including historic conditions provided the best bounding condition even if that future scenario was not realistic. So, with the bounding scenarios in place we considered two different ways of computing future conservation scenarios; implement our selected practices on a) a certain percentage of the row-crop agriculture lands in the watershed (e.g., 10%, 25%, 50%, 75%, 100%) or b) some multiple of in the amount of our selected practices that had been implemented in the past (e.g., 2x, 4x, 8x). The Advisory Panel pointed out that using the percentages provides a

more generic approach that can be more easily interpreted and applied conceptually to other watersheds whereas interpreting the factorial increase approach is much more difficult. When selecting the scenarios, we balanced the need between having realistic scenarios, relative to the historic densities of practices, with the need for scenarios that would likely generate significant improvement in habitat (water quality and flow) and biological communities. Balancing these needs would give us with dose-response curves that would provide both detectable and meaningful comparisons of costs and benefits within and among watersheds and subwatersheds. Ultimately, the Advisory Panel selected two scenarios, where we would implement the selected conservation practices on 25% and 50% of the row crop agriculture lands in each watershed. With these selections we ended up with four scenarios to provide a broad gradient for our dose-response relationships; a) current conditions, 25% BMP scenario, c) 50% BMP scenario, and d) historic conditions.

Conservation practices were divided into practices that could be implemented simultaneously (e.g., cover crop, nutrient management and filter strips) and practices that were mutually exclusive (e.g. conservation tillage and pasture/hay planting). For the 25% and 50% scenarios, conservation practices that were not mutually exclusive were placed, without restriction, across 25% and 50% of row-crop lands. Mutually exclusive practices were placed in relative proportion to their historic implementation based on an analysis of the 2010 NCP database. (See analysis of the NRCS NCP database analysis described above). Conservation practices that were not mutually exclusive were not restricted in where they could be applied for either scenario. Filter strip acreage was determined by conducting an intersect in ArcMap between stream reaches in the NHD+ and row crop lands, so that 25% or 50% of the stream length was given a 100-ft filter strip on each side of the stream. These scenarios were established in coordination with Dr. Amirpouyan Nejadhashemi, who then carried out the SWAT modeling component of the project under Coop Agreement: 68-7482-10-513.

We developed dose response curves for the outlet of each watershed to relate key water quality, flow, and biological metrics across the four conservation scenarios. The iterative analytical process by which key water quality, flow, and biological metrics were selected for inclusion in our dose-response analyses to assess the costs and benefits of our conservation scenarios are detailed in the complimentary Phase I report of this project (Sowa et al. 2011). However, for the purpose of interpreting the results in the following sections of this report it is important to note that our Phase 1 analyses identified two measures of fish community health that consistently revealed significant relations with numerous water quality and flow variables and were the focus of our Phase 2 analyses. Specifically, these were the Index of Biotic Integrity (IBI) and the percent of species that are considered intolerant (% Intolerant) (Karr 1981; Lyons 1996; and Wang et al. 1997). The IBI is a multimetric index that measures the overall biotic integrity or health of the fish community. The original IBI consisted of 12 metrics and was developed for the Midwest United States (Karr 1981). Over the years the original IBI has been modified and customized to specific geographic regions, and successfully used to assess biological integrity of streams (Lyons 1992, Lyons et al. 1996, Roth et al. 1996, Lammert and Allan 1999). Our IBI scores are based on the warmwater stream IBI methods from Lyons (1992). Both the IBI and %Intolerant metric have been shown to be good measures of stream health that respond to a variety of habitat parameters, including water quality and flow and that are also sensitive to agricultural and other impacts (Robertson et al. 2006; Wang et al. 2006).

For each key variable, limiting conditions for the fish community was identified through visual interpretation using wedge plots to identify ceilings and thresholds following the methods of Wang

et al. (2007) and Brenden et al. (2008). The threshold for limiting conditions represents the value of a particular habitat variable (e.g. nutrient concentration) above or below which a biological metric (IBI or % Intolerant) cannot attain a maximum score. Generally, as the value of the habitat variable continues to increase or decrease above the initial limiting threshold value, the maximum potential biological response score will continue to decrease resulting in a ceiling for the maximum attainable value for a biological metric for a given value of the habitat metric (Sowa et al. 2011; Figure 3). The maximum (unlimited) IBI score is 100. From our wedge plot and other analyses in Phase 1 we considered the maximum IBI score of 100 as not limited. For % Intolerant a score of 40 was considered not limited, though some sites may achieve values much higher than that. For each of these biological metric values there are corresponding threshold values for each of the habitat variables that revealed significant wedge plot relations in Phase 1 of our project (Table 1, Figure 3).

Table 1. Key water quality variables identified in Sowa et al. (2011) as limiting for two different measures of biotic potential (fish IBI and % Intolerant scores) across southern Michigan and Wisconsin.

Variable	IBI	% Intolerant	Description
NSURQ	X		Average annual Nitrate in the surface runoff in the local subwatershed
SOLP		X	Average soluble phosphorus in the surface runoff in the local subwatershed
Spr1 NO3		X	Average nitrate concentration during the early spring rising hydrograph
Spr1 ORGP	X		Average organic phosphorus concentration during the early spring rising hydrograph
Spr2 ORGP	X	X	Average organic phosphorus concentration during the late spring falling hydrograph
Sum NO3		X	Average nitrate concentration during the summer
Sum NH4		X	Average ammonia concentration during summer
Sum ORGP	X		Average organic phosphorus concentration during the summer
Sum TP	X	X	Average total phosphorus concentration during summer
Sum SEDCONC	X		Average sediment concentration during summer
FW ORGP	X	X	Average organic phosphorus concentration during the fall-winter

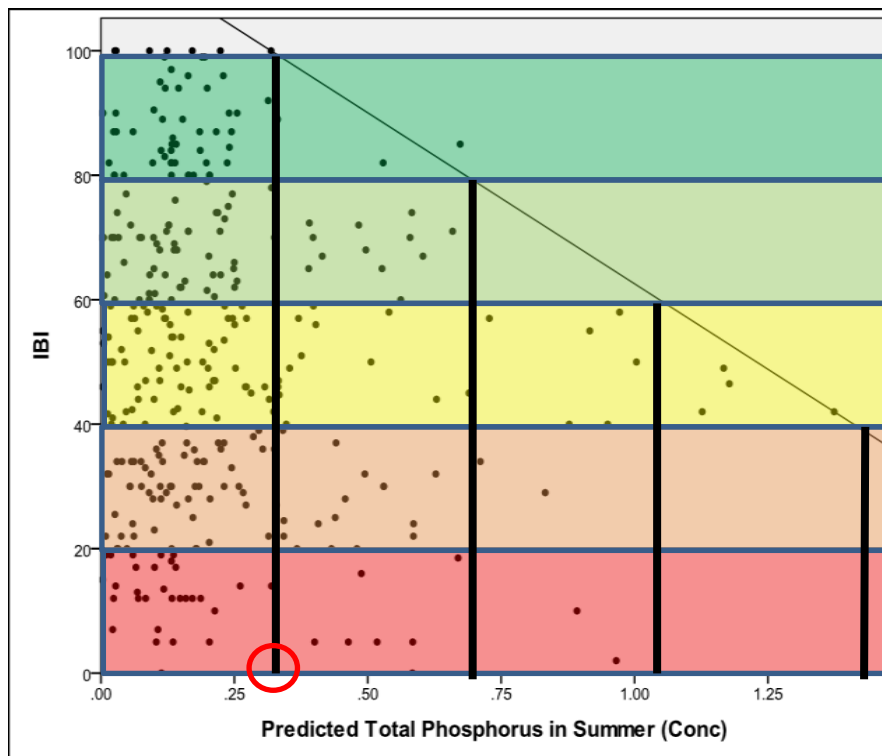


Figure 3. A wedge plot showing the presence of high IBI scores at low total phosphorus concentrations, but above some limiting concentration (circled in red) the highest scores become limiting and are increasingly limited as concentrations continue to increase above that point. Using this wedge or “ceiling,” we can estimate the maximum potential IBI score for any location based on the total phosphorus concentration at that location.

Because most of the variables in Table 1 are seasonal values it was difficult to compare our threshold values with existing thresholds from the literature. Also, most existing work has focused on wadeable (1st to 3rd or 4th order) streams whereas our thresholds cover wadeable to non-wadeable (Robertson et al. 2006; Wang et al. 2006). One exception was the work by Rankin et al. (1999) that established relations between IBI values and various water quality metrics for Ohio streams. This work covered four stream sizes; headwater, wadeable, small river and large river. For each stream size there were three use designations and established recommended water quality criteria for each; Exceptional Warmwater Habitat, Warmwater Habitat, and Modified Warmwater Habitat (Table 2). The only water quality parameter we could compare to this study was our Total Phosphorous during the summer hydroperiod (see Sowa et al. 2011). Our threshold value of 0.32 mg/L for IBI is comparable to the statewide criteria for MWH and also the WH. However, our threshold value is significantly higher than the criteria for the smaller streams and all of the EWH designations.

Table 2. Proposed statewide criteria for Total Phosphorous concentrations (mg/L) for four stream sizes and three designated uses for Ohio streams (Rankin et al. 1999); Exceptional warmwater habitat (EWH), warmwater habitat (WH), and modified warmwater habitat (MWH). Bold values are those comparable to threshold value we identified as no longer limiting for our IBI metric.

	EWH	WH	MWH
Headwater	0.05	0.08	0.34
Wadeable	0.05	0.10	0.28
Small River	0.10	0.17	0.25
Large River	0.15	0.30	0.32
Average	0.09	0.16	0.30

We then evaluated the conservation scenarios for each subwatershed across the four selected watersheds in order to;

- 1) identify the most limiting habitat variable within each subwatershed under each scenario,
- 2) quantify the predicted amount of improvement in the fish community metrics under each scenario and,
- 3) identify which subwatersheds we can improve under each conservation scenario to the point that the fish community is no longer limited by water quality or flow alterations resulting from nonpoint source impacts associated with row-crop agricultural.

Since the intent of our analyses was to identify subwatersheds where biological potential could be improved through conservation practices applied to row-crop agriculture, we had to ensure we evaluated row-crop agriculture impacts and BMP benefits in context of inherent biological potential and /or other disturbances that were limiting the fish community in each subwatershed. Generating this context was actually addressed in Phase 1 of this project where we used wedge plot analyses to identify several natural features and disturbances other than row-crop agriculture (i.e., non-target disturbances) that were limiting the fish community metrics at many locations across the regional project area.

So we first quantified the maximum attainable values for each fish community metric, within each subwatershed, based on inherent natural ceilings or ceilings caused by non-target disturbances. We then calculated the maximum potential IBI and % Intolerant score for each subwatershed based on the most limiting water quality or flow variable and divided that value by the maximum potential score for the same subwatershed based on the ceilings (if any) imposed by natural variables and/or non-target threats (Table 3). The resulting value is the percent (%) of maximum IBI (or % of maximum % Intolerant) attainable based on the most limiting water quality or flow variable. This calculation is illustrated in the following equation;

$$\%MxIBI = (WQIBI / \text{MIN}(\text{NatIBI}, \text{NTIBI})) * 100$$

in which the %MxIBI is the % maximum IBI, WQIBI is the maximum potential IBI based on the most limiting water quality variable, and the MIN(NatIBI or NTIBI) is the lowest value between the maximum potential IBI based on the most limiting natural variable or non-target threat variable. The % maximum IBI is capped at 100, so a value of 100 was used whenever a value greater than 100 was obtained.

Table 3. Examples showing how we calculated % Maximum IBI scores for each subwatershed. The % Maximum IBI score represents the IBI score relative to the maximum attainable score, which may be limited by natural watershed features or non-targets threats (i.e., watershed cattle density or percent impervious in watershed)

Example Subwatershed	Water Quality Variable	Natural Variable	Non-Target Threat Variable	Percent Maximum IBI
#1	100	100	100	100%
#2	81	100	100	81.0%
#3	81	96	100	84.4%
#4	81	100	96	84.4%
#5	81	96	97	84.4%
#6	96	91	100	100%

If. Generate cost estimates for each scenario.

The purpose of generating cost estimates was to estimate the typical installation costs associated with each of our conservation scenarios, which could then be assessed against the predicted biological improvements (i.e., benefits). Our assessments of costs and benefits focused only on improvement in IBI scores for several reasons. First the relationships of the IBI with habitat variables were much stronger than those of the %Intolerant metric. Second, the %Intolerant metric was rarely limited across the four selected watersheds, and the IBI was influenced by a much wider selection of water quality variables than % Intolerant. Finally, the IBI is a more comprehensive measure of fish community health and we find that it is more widely recognized, embraced, and more easily understood by variety of audiences.

Individual practice costs were based on the 2012 NRCS statewide typical practice costs, which were obtained online from the Michigan Field Office Technical Guide at the following URL: http://efotg.sc.egov.usda.gov/references/public/MI/Statewide_Typical_Practice_Cost_FOTG2012.pdf The statewide typical costs for practice installation is provided for general information to assist with comparing different practices and to provide a general estimate of costs. However, many site specific variables determine actual costs. Except for filter strips these per acre practices costs were multiplied by the corresponding acreage for 25 and 50% of the total row-crop lands in each subwatershed. For filter strips costs were estimated on per unit length so we multiplied these costs by the corresponding length of 25 and 50% of the total length of stream in each subwatershed. Finally, we summed these costs across all practices to generate the overall cost estimates for

subwatershed under each conservation scenario. We also used the dose-response graphs to estimate the cost at which water quality and flow conditions are predicted to no longer be limiting the fish community, as measured by the IBI, for the outlet of each watershed.

1g. Work with the Advisory Panel to compare and contrast the conservation scenarios.

Instead of working collectively through our Advisory Panel we took a more opportunistic approach. We worked through individual members of our Advisory Panel to capitalize on opportunities for presenting the interim results to key groups and demonstrate first-hand the potential application of this work to guide strategic conservation. We have also capitalized on a funding opportunity presented to us by the C.S. Mott Foundation, which allowed TNC to hire a Saginaw Bay Project Director. This approach led to many possible applications of this body of work to help many conservation agencies and organizations working in the Saginaw Bay watershed.

1h. Use selected scenarios to develop more specific conservation blueprints and schedules of conservation action.

Instead of rigid blueprints, we have provided a means of setting ecological goals and related conservation action goals. As we started having conversations with our partners it became clear that providing them a means of developing realistic/meaningful goals and then a means of flexibly achieving those goals was much more palatable than devising rigid prescriptions for sets of conservation practices.

1i. Work through the Advisory Panel to develop appropriate outreach and innovative solutions for carrying out the recommendations from task 1h

As with the two preceding tasks we worked opportunistically through our Advisory Panel members and other partners to communicate the results of this work and to devise projects for using the data, knowledge and decision tools to guide strategic conservation in one or more of the selected watersheds. Several case studies of how we are working with local partners in the Cass, Rifle, and Shiawassee River watersheds are detailed in the corresponding results section below.

OBJECTIVE 1 RESULTS

1a. Establish a Saginaw Bay advisory panel

In May of 2011 we established a 10 member advisory panel to help guide our project and provide critical local information to improve our project (Table 4). We held the first meeting of this advisory panel on June 1, 2011 in Bay City, MI and received excellent feedback from the relatively small number of participants. To address the low turnout issue we scheduled additional meetings with subsets of the panel members that could not make the meeting in June. The purpose of these first meetings was to introduce the

relevant stakeholders to our project and to help us answer three key questions;

1. What subset of BMPs should be incorporated into the future conservation scenarios?
2. What 3-5 subbasins of the Saginaw Bay drainage should we select for developing the future conservation scenarios?
3. How should we develop our future conservation scenarios to maximize the information gained from our dose-response analyses?

Table 4. List of Advisory Panel Members and their Affiliations

Mike Kelly	Saginaw Bay Watershed Initiative Network
Charlie Bauer	Michigan Department of Environmental Quality
Jim Hergott	Saginaw Bay RC&D (retired)
Dawn Hergott	Arenac County Conservation District
Melissa Higbee	Shiawassee County Conservation District
Patti Copes	Arenac County Conservation District
Steve Shine	Michigan Department of Agriculture
Jim Kratz	Tuscola County Conservation District
Lisha Ramsdell	Huron Pines RC&D
Abigail Ertel	Huron Pines RC&D
Jeanette Renn	Huron County Conservation District
Tom Wert	Shiawassee County Conservation District

1b. Select priority subbasins for generating future conservation scenarios

Working with our Advisory Panel we selected four priority subbasins of the Saginaw Bay drainage; Cass, Pigeon/Pinnebog, Rifle, and Shiawassee River watersheds (Figure 4). These watersheds were selected because they are consistently cited as among the highest priority watersheds in the region (e.g., <http://www.saginawbayrcd.org/watersheds.shtml>). In addition, they represent a spectrum of agricultural influence ranging from 25% agriculture in the Rifle to 80% agriculture in the Pigeon/Pinnebog. Having a range of agricultural prevalence will increase the likelihood that we will get significantly different “dose-response” curves between conservation conditions in the watershed and the various water quality, flow, and biological endpoints. It also ensured that the cost estimates for achieving different biological conditions will be significantly different across the watersheds and thus present us and our partners with a wide range of cost-benefit alternatives to select from. Also of note, the Rifle, Shiawassee, and Pinnebog Rivers have also been identified as ecoregional biodiversity conservation priorities (TNC 2001).

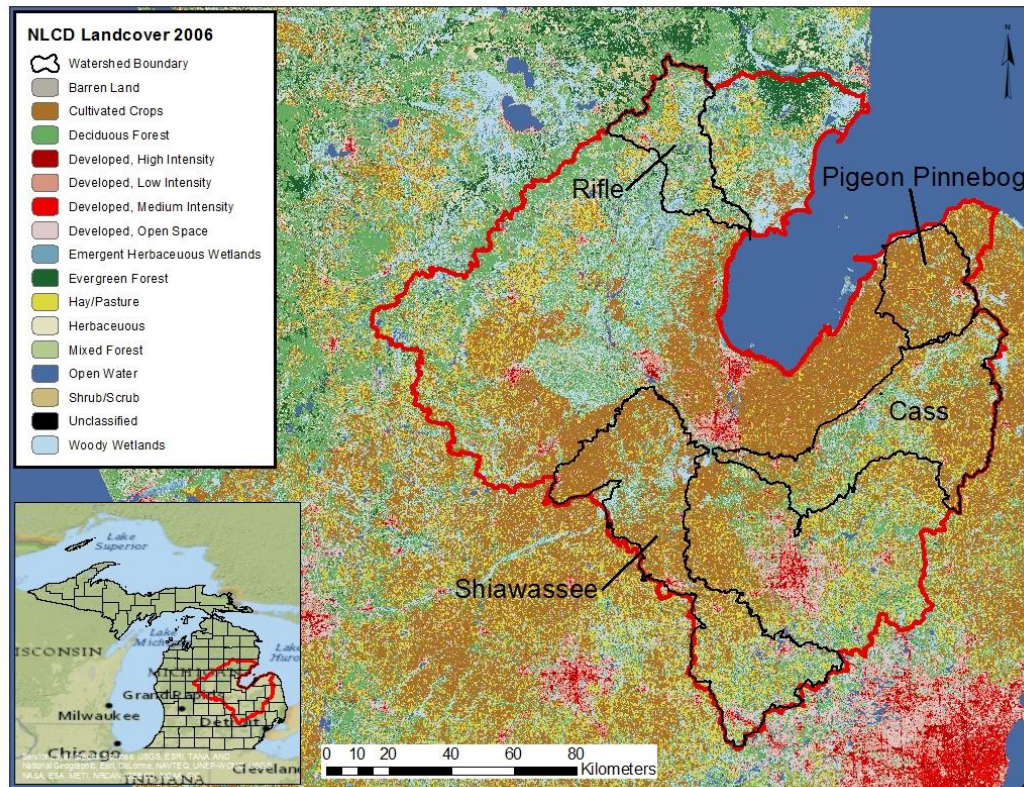


Figure 4. Location of Saginaw Bay drainage (inset map) and the four priority watersheds that are the focus of our project.

1c. Quantify the amount of all NRCS conservation practices within the local catchment and overall watershed of all stream reaches containing fish community collections within the Saginaw Bay drainage and larger project area.

The most frequently implemented conservation practices within our target watersheds are shown in Figure 5 and summarized in Table 5.

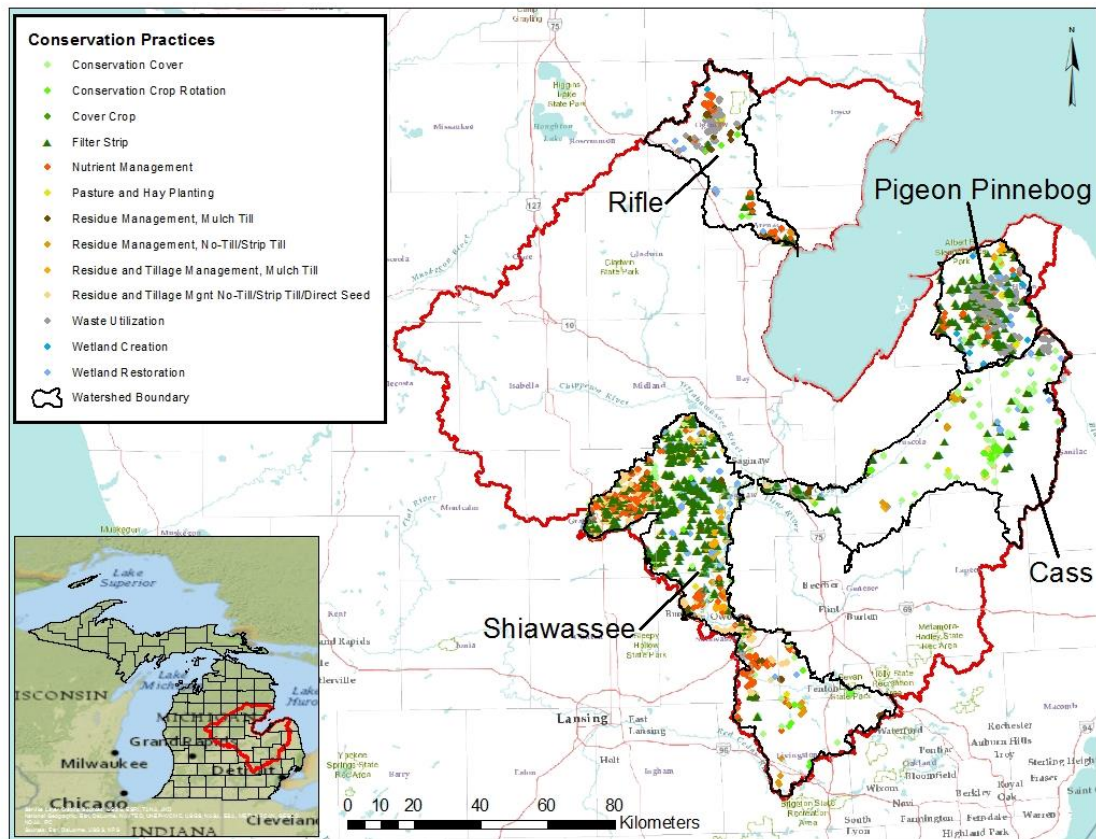


Figure 5. NRCS conservation practices from the 2010 NCP database showing practices implemented in the four priority subwatersheds of Saginaw Bay during 1999-2009.

Table 5. NRCS conservation practices implemented between 1999-2009 within and across the four Saginaw Bay watersheds where our Phase 2 study was focused. Practices included in the conservation scenarios are noted.

Practice Name	Included in Models	Overall	Frequency of Implementation			
			Cass	Pigeon/ Pinnebog	Rifle	Shiawassee
Upland Wildlife Habitat Management	No	1636	179	267	123	1067
*Nutrient Management	Yes	1381	64	482	186	649
Conservation Crop Rotation	Yes	1188	150	412	69	557
Pest Management	No	1171	17	445	182	527
Filter Strip	Yes	974	126	159	31	658
*Waste Utilization	Yes	588	31	385	117	55
Access Control	No	404	40	271	2	91
Conservation Cover	Yes	327	102	46	12	167
Residue and Tillage Management, No-Till/Strip Till/Direct Seed	Yes	319	25	0	2	292
†Residue Management, Mulch Till	Yes	212	61	0	50	101
Wetland Creation/Restoration	Yes	201	24	34	14	129
Early Successional Habitat Development/Management	No	188	44	50	20	74
Wetland Wildlife Habitat Management	No	180	12	41	26	101
†Residue and Tillage Management, Mulch Till	Yes	126	8	36	12	70
Residue Management, No-Till/Strip Till	Yes	108	33	3	0	67
Tree/Shrub Establishment	No	87	7	3	56	21
Cover Crop	Yes	75	10	50	5	10
Windbreak/Shelterbelt Establishment	No	75	6	20	6	43
Pasture and Hay Planting	Yes	47	1	13	14	19

*Nutrient Management and Waste Management were combined into one practice during SWAT modeling.

†Residue Management, Mulch Till and Residue and Tillage Management, Mulch Till were combined into a single mulch till (conservation tillage) practice during SWAT modeling.

1d. Use the information from task 1b to help select 10-15 NRCS conservation practices to ensure we develop realistic future conservation scenarios.

We evaluated the most frequently utilized conservation practices within the study area (Table 5) to determine which practices were typically applied to row-crop agricultural lands and to determine the applicability of each practice to our goals (nutrient, sediment and flow restoration). This review is summarized in Table 6. All practices generally not implemented on row-crop lands were excluded from the conservation scenarios. Pest management was the only practice, generally implemented on row crop lands, that was excluded by these criteria.

Table 6. A summary of whether the most frequently implemented practices in the region (see Table 5) are associated with row crop agricultural and how they generally influence sedimentation, streamflow, nutrients, temperature, and contaminants. Positive rating numbers indicate benefits, while negative numbers indicate impacts with numbers corresponding with: 3 = high, 2 = moderate, 1 = low, 0 = no influence. (Modified from Fore 2012)

Conservation Practice	Row Crop	<u>Ecological Benefit Ratings</u>						
		Sediment	Streamflow	Nutrients	Phosphorus	Nitrogen	Temperature	Contaminants
Conservation Cover	Yes	3	3	3	3	2	2	0
Pasture and Hay Planting	Yes	3	3	3	3	3	3	2
Wetland Creation	Yes	3	3	3	3	3	3	3
Wetland Restoration	Yes	3	3	3	3	3	3	3
Cover Crop	Yes	3	2	2	2	2	2	-1
Filter Strip	Yes	3	1	2	3	3	1	1
Residue and Tillage Management, No-Till/Strip Till/Direct Seed	Yes	3	2	2	2	3	2	-2
Residue Management, No-Till/Strip Till	Yes	3	2	2	2	3	2	-2
Residue and Tillage Management, Mulch Till	Yes	2	1	2	2	2	1	0
Residue Management, Mulch Till	Yes	2	1	2	2	2	1	1
Conservation Crop Rotation	Yes	1	1	1	1	2	1	1
Nutrient Management	Yes	1	0	1	1	1	0	0
Pest Management	Yes	1	1	0	0	0	1	-1
Access Control	No	3	1	1	1	1	1	1
Tree/Shrub Establishment	No	2	3	2	1	2	3	2
Upland Wildlife Habitat Management	No	2	3	1	1	1	3	2
Wetland Wildlife Habitat Management	No	2	2	1	1	1	2	2
Windbreak/Shelterbelt Establishment	No	2	2	2	2	1	2	2
Early Successional Habitat Development/Management	No	1	0	0	1	0	-1	0
Waste Utilization	No	0	0	1	1	1	0	0

Based on our review of the prevalence of conservation practices in the region (Table 5), the applicability of the practice on row-crop lands, the ecological benefits of the practice to our goals, and expert input from our Advisory Panel on the relative benefits of less prevalent practices (e.g., wetland restoration) we ended up with 10 practices to include in our SWAT conservation scenarios (Table 7).

Table 7. Ten conservation practices to be included in conservation scenarios

- Nutrient Management/Waste Utilization
- Conservation Crop Rotation
- Filter Strip
- *Conservation Cover
- *Residue and Tillage Management, No-Till/Strip Till/Direct Seed
- *Mulch Till (Residue Mgt, Mulch Till; Residue and Tillage Mgt, Mulch Till)
- *Residue Management, No-Till/Strip Till
- Cover Crop
- *Pasture and Hay Planting
- Wetland Creation/Restoration

*These practices were considered mutually exclusive for implementation

1e*. *Within each selected subwatershed, use SWAT to model changes in physical, chemical, and biological conditions associated with different future conservation scenarios relative to current and historic conditions.*

**Note: The SWAT modeling component of task 1e was carried out by a companion project that is jointly funded by TNC and NRCS CEAP (Coop Agreement: 68-7482-10-513) that was conducted by Dr. Amirpouyan Nejadhashemi, a faculty member within the Department of Biosystems and Agricultural Engineering at Michigan State University.*

Dr. Nejadhashemi and his staff completed SWAT runs using all four scenarios for each watershed. Water quality and flow outputs from the models were then used as inputs to the biological response models that were developed in Phase 1 of the project. Through connecting the SWAT model runs to the biological response models, we developed relationships between conservation practices, water quality and flow variables. As a result, we were then able to express the results of changing our scenarios for BMP intensity in terms of changes in the Index of Biotic Integrity (IBI) and Percent Intolerant Species (% Intolerant).

Index of Biotic Integrity (IBI)

Dose response curves were plotted to evaluate changes in water quality and fish IBI scores with implementation of conservation practices for the outlet of each watershed (Figure 6). Differences in dose-response curves among watersheds did generally correspond with the percentage of agriculture in the watershed, with the Rifle River (~25% AG) having the most natural conditions and the Pigeon (~80% AG) being the most altered (Figure 6). Response curves indicate a greater return on investment with the 25% scenario compared with the 50% scenario across all watersheds, particularly the Pigeon (Figure 6). At the outlet of each river, the Rifle, Cass and Shiawassee are minimally limiting for only one or two variables under current conditions, and the outlets are no longer limiting for any variable with the 25% scenarios. However, individual subwatersheds are

generally more limited than the outlets of these watersheds, and many of these remain limiting even with the 50% scenario (e.g., Figure 7).

Within these four priority watersheds, there was one natural variable, the proportion of fine-textured end-moraine in the watershed, and two non-target watershed disturbances (i.e., not row-crop land use) percent impervious surface and average cattle density in the watershed, with values high enough to limit fish IBI scores. We surmise that the proportion of fine-textured end moraine in the watershed is an indirect measure of the ratio of groundwater to surface water feeding the streams and thus also the thermal regime. Fine-textured end moraine are surficial geologic deposits with high infiltration and are generally associated with cool and coldwater streams (Higgins et al. 2005; Brenden et al. 2008).

Using wedge plot relationships between these variables and IBI scores (from Sowa et al. 2011), we calculated the maximum potential IBI score attainable for each subwatershed. The majority of subwatersheds are not limited by any of these variables (Figure 8). Limitations on fish diversity from the natural variable, percent fine end-moraine in the watershed, were restricted to the Rifle River watershed, where potential IBI scores are substantially reduced in some subwatersheds. Non-agricultural (row crop) threats are restricted to the Rifle River (Cattle) and the headwaters of the Shiawassee River (percent impervious), but these are barely limiting within any subwatershed (Figure 8).

The percent maximum attainable IBI score based on the most limiting water quality or flow variable was calculated, averaged across subwatersheds within each watershed (Table 8), and mapped for each subwatershed (Figure 9). Similar to the outlet of each watershed, average % maximum attainable IBI was highest in the Rifle and lowest in the Pigeon-Pinnebog and there was greater improvement within each watershed between current conditions and the 25% conservation practice scenario, than from 25% to 50% (Table 8). In the current scenario, no subwatersheds were unlimited within the Cass River watershed or the Pigeon-Pinnebog watersheds, while most subwatersheds in the Rifle River watershed were unlimited, as were a few subwatersheds in the Shiawassee headwaters. The Pigeon-Pinnebog subwatersheds clearly have the most impacted IBI scores and the Shiawassee watershed has the most heterogeneity among subwatersheds.

With the 25% conservation practice scenario (Figure 9b), the entire Rifle River watershed is unlimited (Figure 9). In addition, several subwatersheds within the Shiawassee and Cass watersheds are unlimited—including the outlet of both rivers, and the Pigeon-Pinnebog has improved substantially, though no individual subwatershed became unlimited. Under the 50% conservation practice scenario, additional subwatersheds within the Shiawassee and Cass watersheds have improved to unlimited conditions, but there are still no unlimited subwatersheds in the Pigeon-Pinnebog, though further improvement is apparent.

The watersheds where IBI scores improve the most under the 25% and 50% scenarios are throughout most of the Pigeon-Pinnebog watershed, in the upper Cass, and in the middle Shiawassee and Bad River tributary of the Shiawassee (Figure 10). With increasing implementation of conservation practices, the number of subwatersheds limited by nutrients declines, while the number limited by sediment and that are not limited at all increase (Figure 11). Sediment is increasingly the most limiting variable because the slope on the dose-response curves for sediment are generally not as steep as for the nutrient variables (Figure 6). So, even as the amount of sedimentation declines with conservation practices, sedimentation becomes more likely to be the

most limiting variable, because other variables (nutrient concentrations) decline more quickly with the increase in conservation practices, and are thus no longer limiting.

Under the current scenario, most subwatersheds outside of the Rifle River watershed were limiting by three or more water quality variables (Figure 12A). In fact, many subwatersheds were limited by five or more, and most Pigeon-Pinnebog watersheds were limited by all seven variables. With the 25% and 50% scenarios, many subwatersheds experienced reductions in the number of limiting variables (Figure 12 and Figure 13). Interestingly, the watersheds that experienced the greatest decreases in the number of limiting variables (Figure 13) did not always align with the subwatersheds that experienced the largest increase in the percent maximum attainable IBI scores based on the most limiting variable (Figure 10).

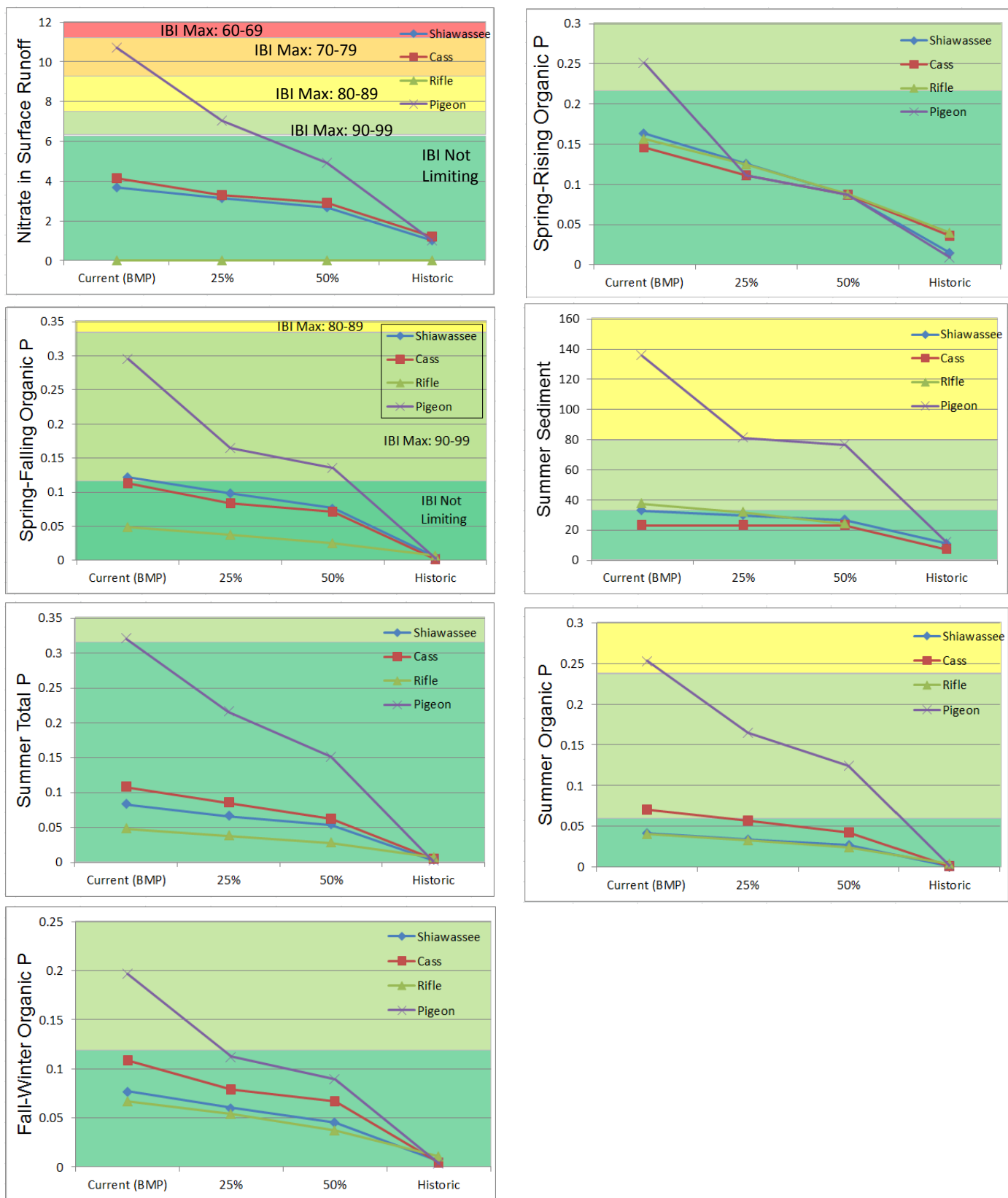


Figure 6. Dose-response curves showing water quality variables at the watershed outlet for current conditions, conservation practices across 25% and 50% of the watershed, and historic conditions for each of the four priority watersheds. Color shading indicates threshold values for fish IBI scores, with values falling within the dark green no longer limiting IBI scores for each key variable.

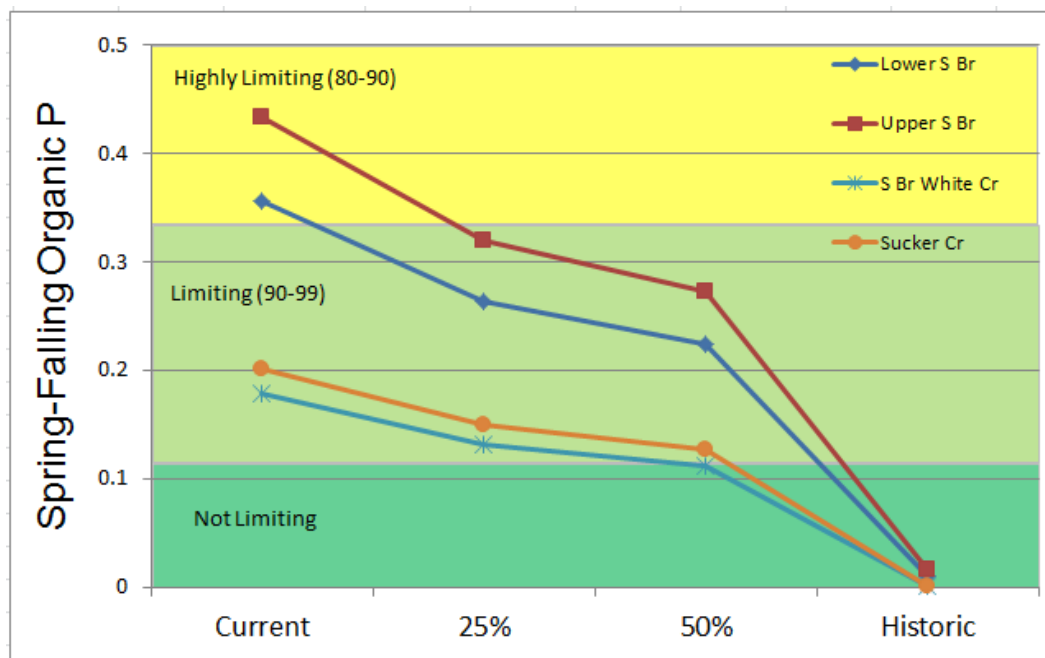


Figure 7. Dose-response curves showing water quality variables for four Cass River tributary subwatersheds for current conditions, conservation practices across 25% and 50% of the watershed, and historic conditions for each of the four priority watersheds. Color shading indicates threshold values for fish IBI scores, with values falling within the dark green no longer limiting IBI scores for each key variable.

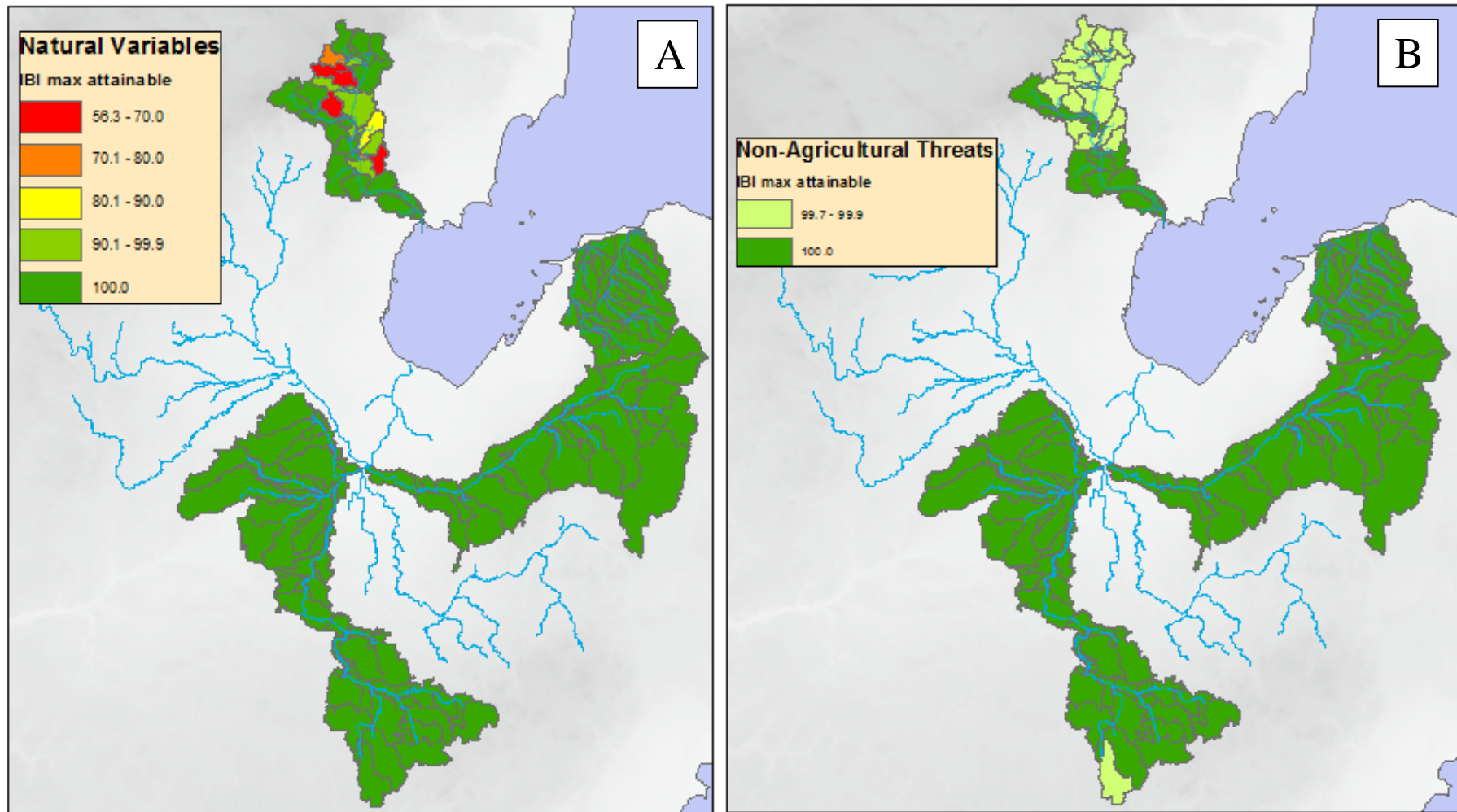


Figure 8. Maximum attainable IBI score for each subwatershed across the study areas based on predicted limitations due to key A) natural variables (the proportion of fine end-moraine in the watershed) and B) non-agricultural threats (percent impervious surface and average cattle density in the watershed).

Table 8. Average percent (%) maximum attainable IBI across subwatersheds for each focal watershed.

Watershed	Current	25%	50%
Cass	90.2%	93.3%	94.1%
Shiawassee	90.4%	93.7%	96.1%
Rifle	99.8%	100%	100%
Pigeon-Pinnebog	71.9%	82.7%	85.2%

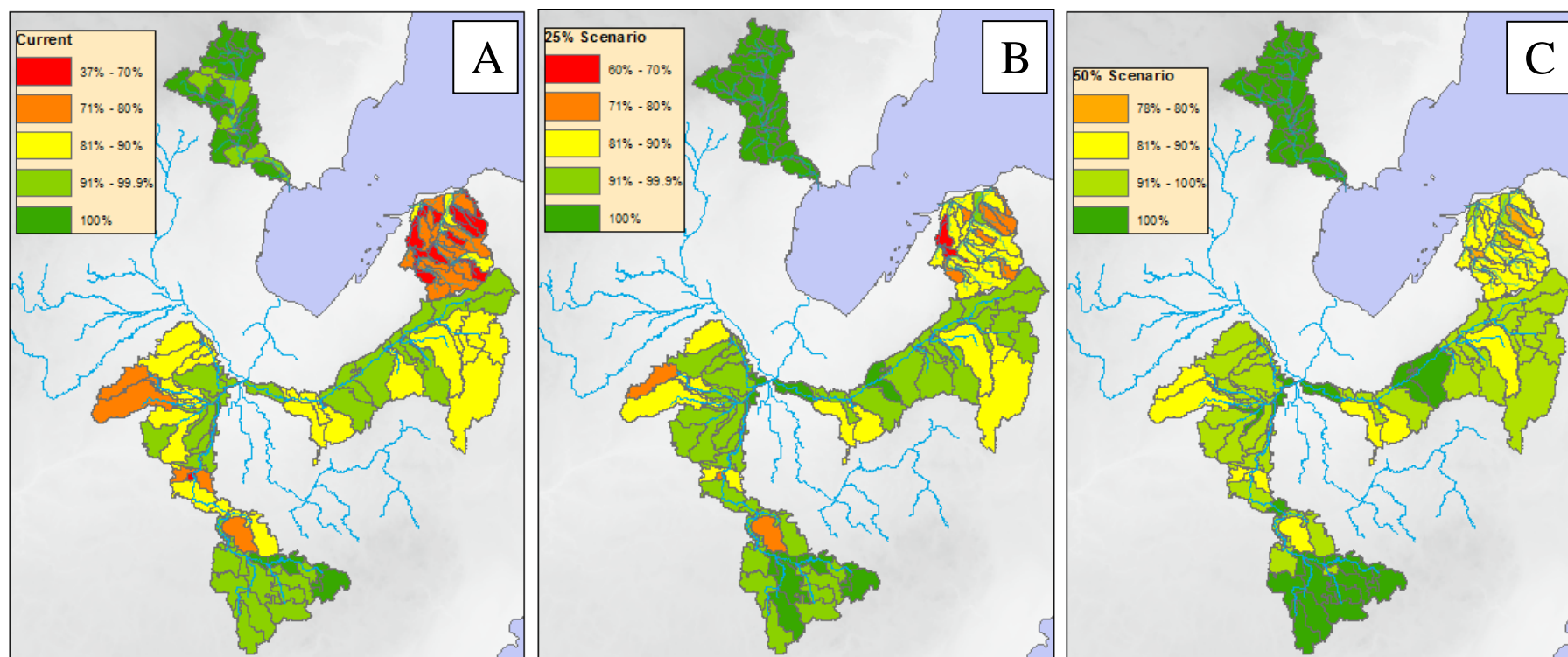


Figure 9. Percent maximum attainable IBI score based on the most limiting water quality or flow variable for each subwatershed across the four priority watersheds for A) current conditions, and B) 25% and C) 50% of the row crop acres in conservation practices. Subwatersheds in dark green are not limited by water quality or flow variables, while subwatersheds in orange or red are extremely limited.

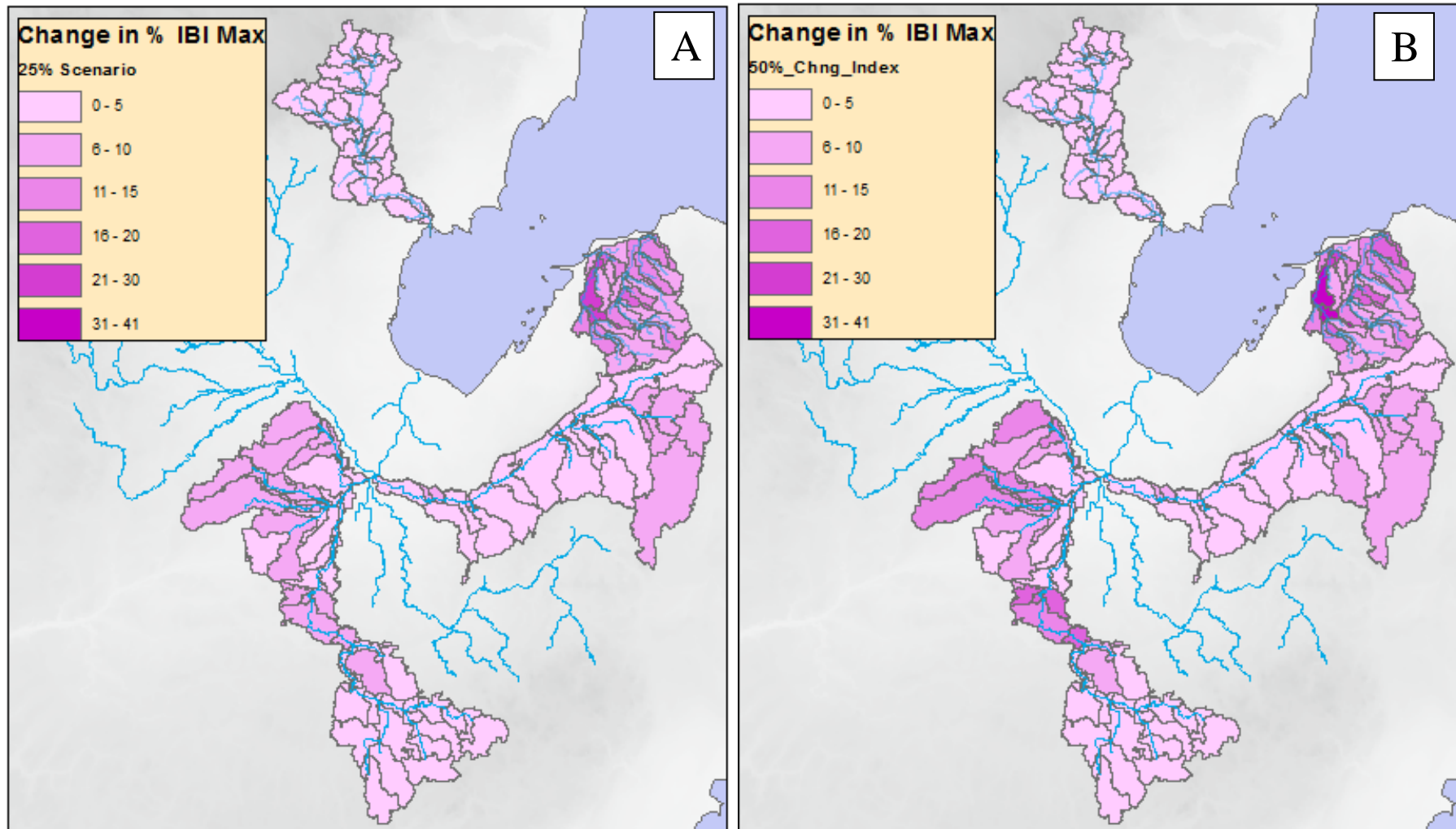


Figure 10. Change (increase) in the percent maximum attainable IBI score based on the most limiting water quality or flow variable for each subwatershed across the four priority watersheds for A) 25% and B) 50% of the row crop acres in conservation practices. Subwatersheds with darker purple colors experienced greater improvement in IBI scores.

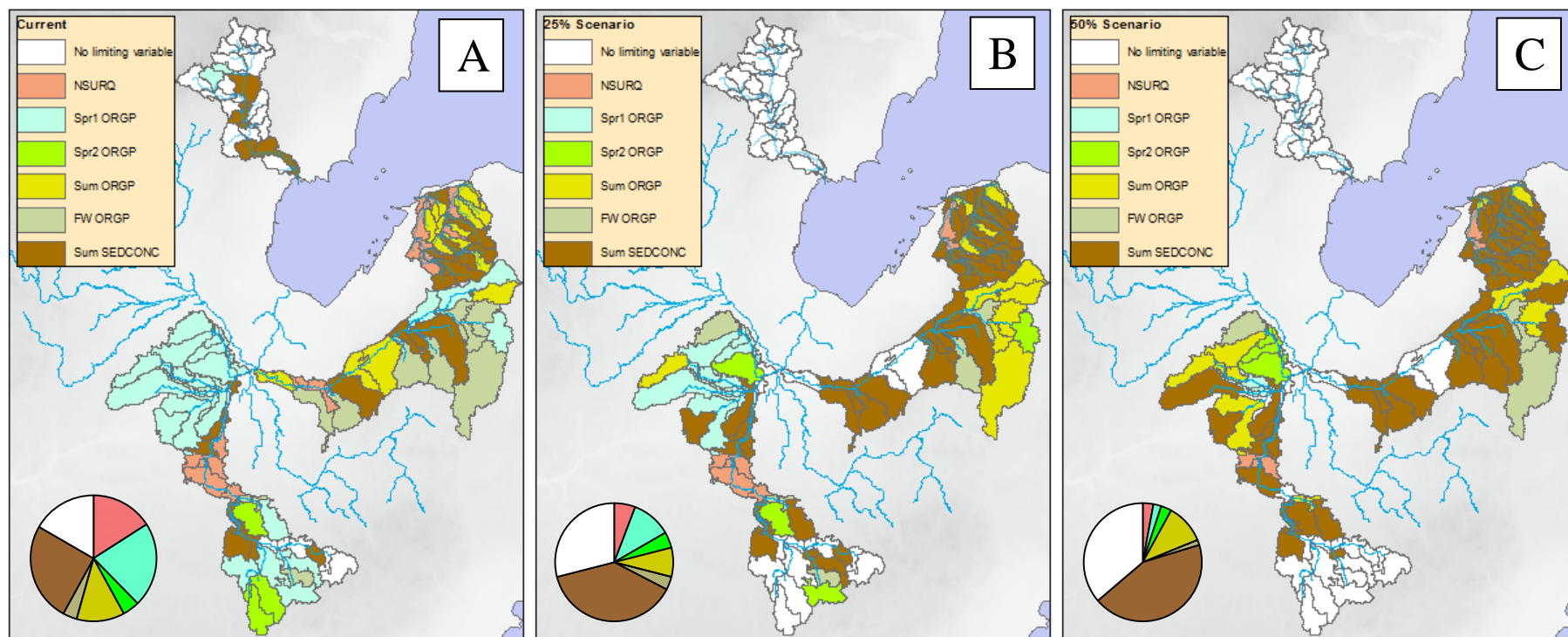


Figure 11. The most limiting water quality variable to IBI scores within each subwatershed across the four priority watersheds for A) current conditions, and B) 25% and C) 50% of the row crop acres in conservation practices.

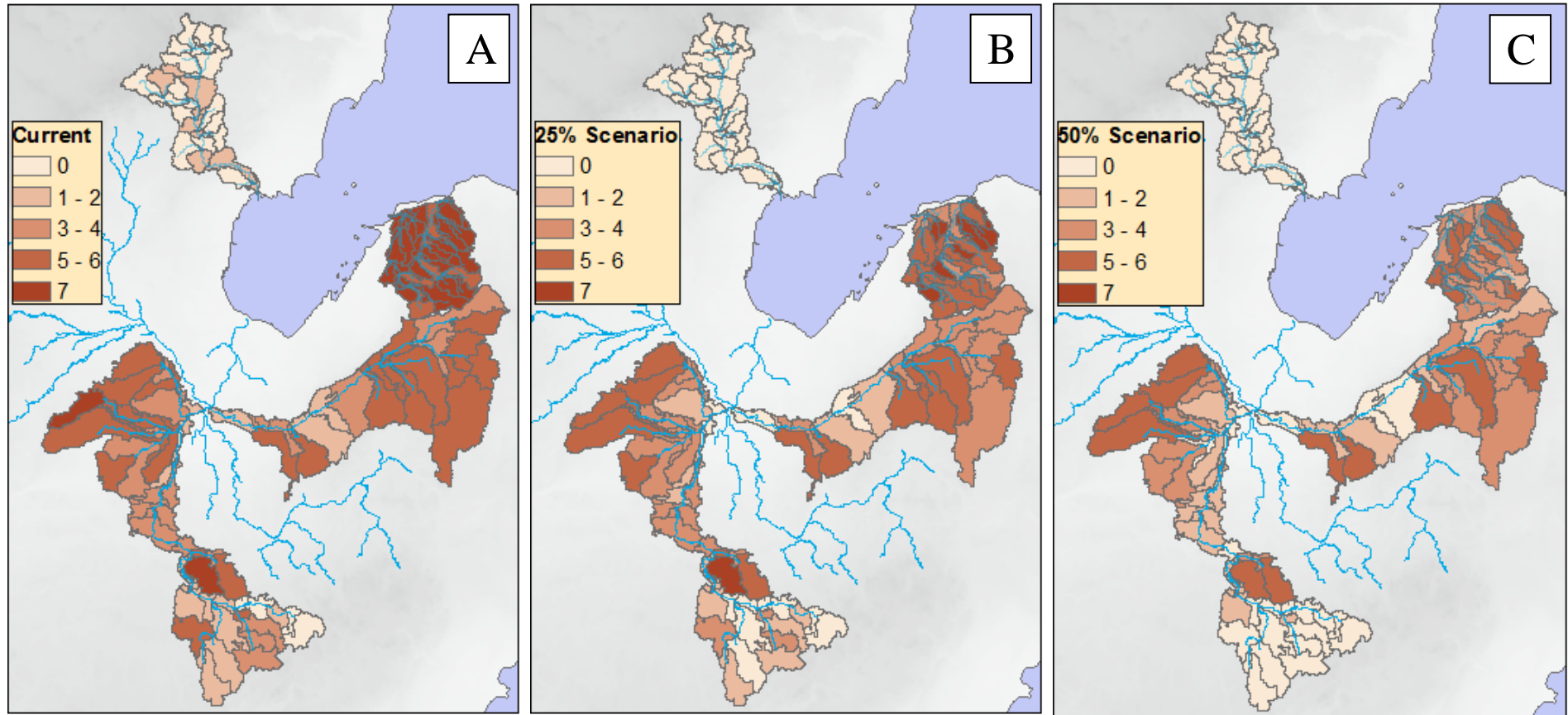


Figure 12. The number of limiting water quality variables to IBI scores within each subwatershed across the four priority watersheds for A) current conditions, and B) 25% and C) 50% of the row crop acres in conservation practices.

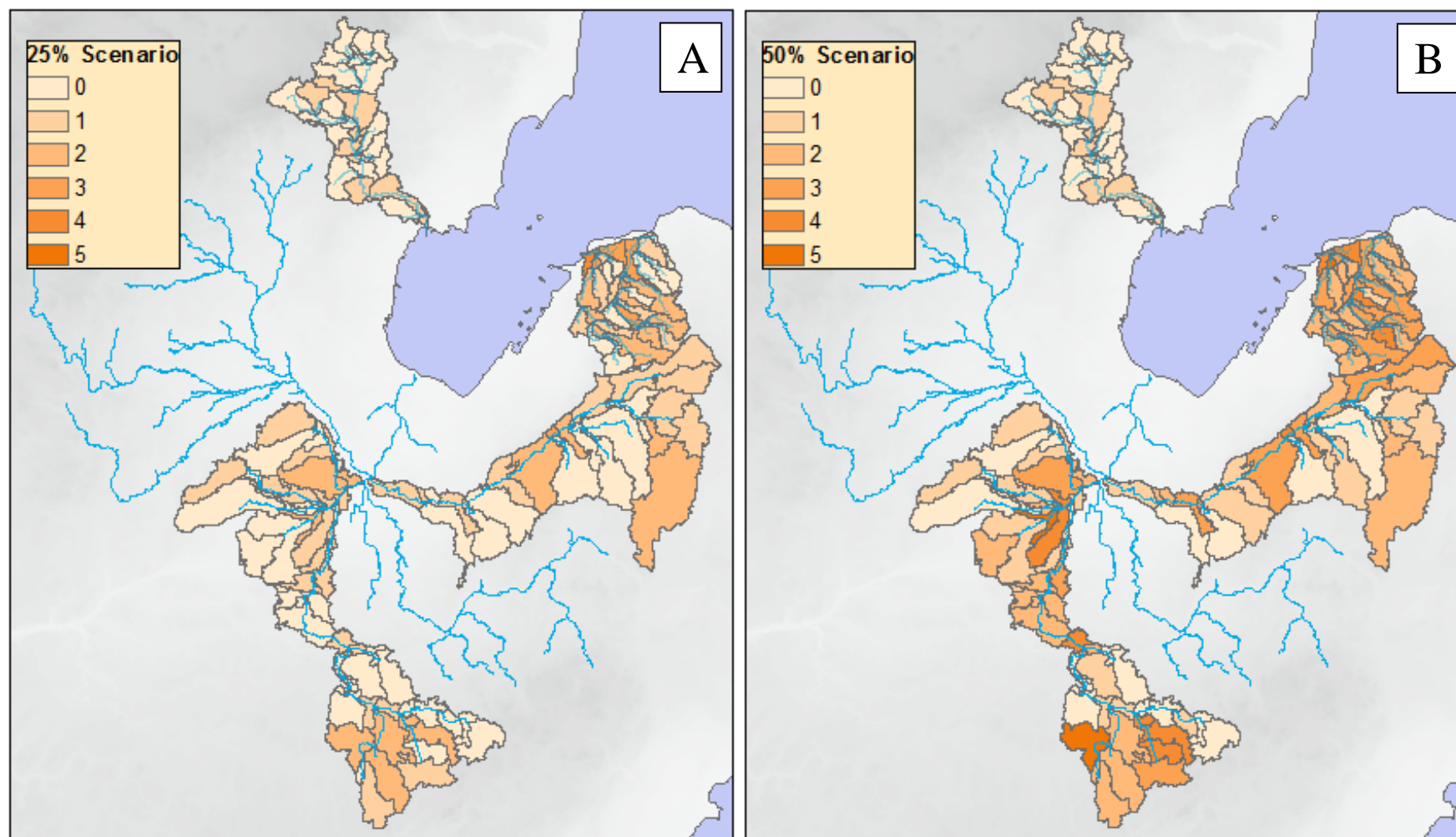


Figure 13. Decrease in the number of limiting water quality variables to IBI scores for each subwatershed across the four priority watersheds from current conditions to A) 25% and B) 50% of the row crop acres in conservation practices. Subwatersheds with darker orange colors experienced a greater decrease in limiting water quality variables.

Percent Intolerant Species

Dose response curves were plotted to evaluate changes in water quality and % Intolerant fish species with implementation of conservation practices for the outlet of each watershed (Figure 14). As with IBI response graphs, dose-response curves differed among watersheds, with the Rifle River generally having the lowest nutrient concentrations and the most gradual decrease in slope with increasing conservation practices, and the Pigeon River having the greatest concentrations and slope. At the outlet, % Intolerant species are not limited by any water quality variable in the Rifle, Shiawassee and Cass Rivers. Conversely, % Intolerant species are highly limited in the Pigeon-Pinnebog by the amount of phosphorus in runoff within the local catchment, but no other water quality variable is limiting.

For % Intolerant, there was one natural variable, the watershed groundwater index value (Aquatic Gap citation), and no non-agricultural threat variables limiting within these watersheds. Using wedge plot relationships (Sowa et al. 2011), we calculated the maximum potential IBI score attainable within each subwatershed (Figure 15). Low groundwater contributions limit the potential % Intolerant throughout most of the Pigeon-Pinnebog and Cass watersheds (Figure 15a).

The percent maximum attainable % Intolerant fishes score based on the most limiting water quality variables was calculated, averaged across subwatersheds within each watershed (Table 9), and mapped for each subwatershed (Figure 16). Similar to the outlet of each watershed and for IBI score relationships, average % maximum attainable IBI was highest in the Rifle and lowest in the Pigeon-Pinnebog (Table 9). However, unlike IBI scores the difference in improvement from current conditions to the 25% conservation practice scenario and from 25% to 50% differed among watersheds. In the current scenario, no subwatersheds were limited for % Intolerant in the Rifle River, roughly only half were limited in the Shiawassee, only a few were limited in the Cass River, and all subwatersheds were limited in the Pigeon-Pinnebog. Under the 25% scenario, improvement can be seen in several Cass and Shiawassee River watersheds, and on Pigeon-Pinnebog subwatershed went from highly limited to not limited by water quality variables. Further improvement can be seen in the 50% scenario throughout each of these watersheds. Across scenarios the most improvement in % Intolerant species limiting conditions occurs in the headwaters of the Pigeon-Pinnebog, the headwaters of the Cass, and in the Bad River tributary of the Shiawassee watershed (Figure 16 and Figure 17).

Under the current scenario, most subwatersheds limiting for % Intolerant were only limiting for one variable (Figure 18A), the amount of phosphorus in runoff within the local catchment. Under the 25% scenario, that is the only variable that remains limiting and it remains limiting for all but a few of the subwatersheds where it was limiting under current conditions (Figure 18B). Several more subwatersheds become unlimited under the 50% scenario, including a cluster of subwatersheds in the Bad River tributary of the Shiawassee (Figure 18C). The alignment between the greatest decrease in the number of limiting variables (Figure 19) and the percent maximum attainable % Intolerant fishes score based on the most limiting variables (Figure 17) is greater than that for those measure for IBI, especially under the 50% scenario. But there are some important differences between the two measures that should be considered.

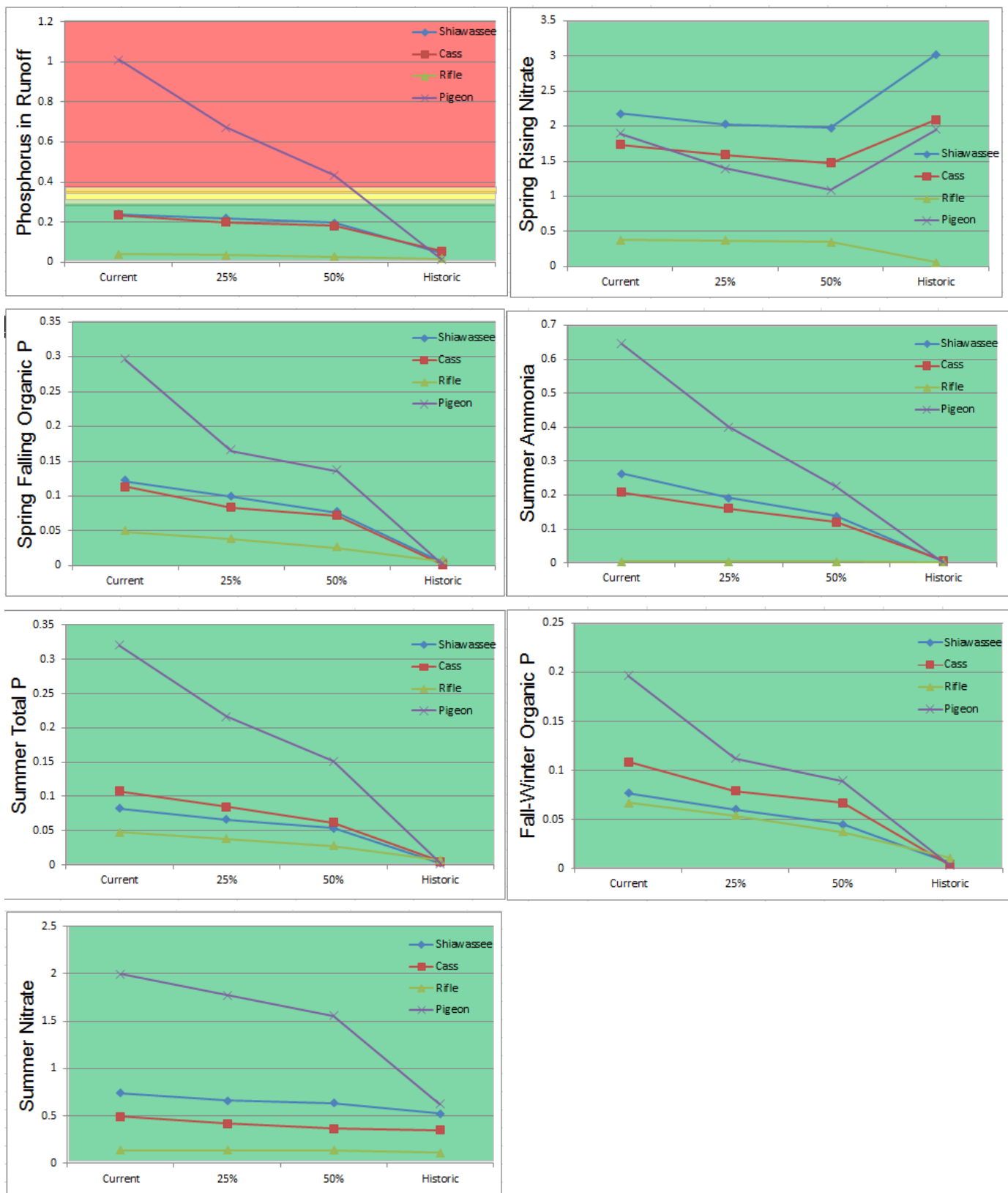


Figure 14. Dose-response curves showing water quality variables at the watershed outlet for current conditions, conservation practices across 25% and 50% of the watershed, and historic conditions for each of the four priority watersheds. Color shading indicates threshold values for % Intolerant Fish, with values falling within the dark green no longer limiting IBI scores for each key variable.

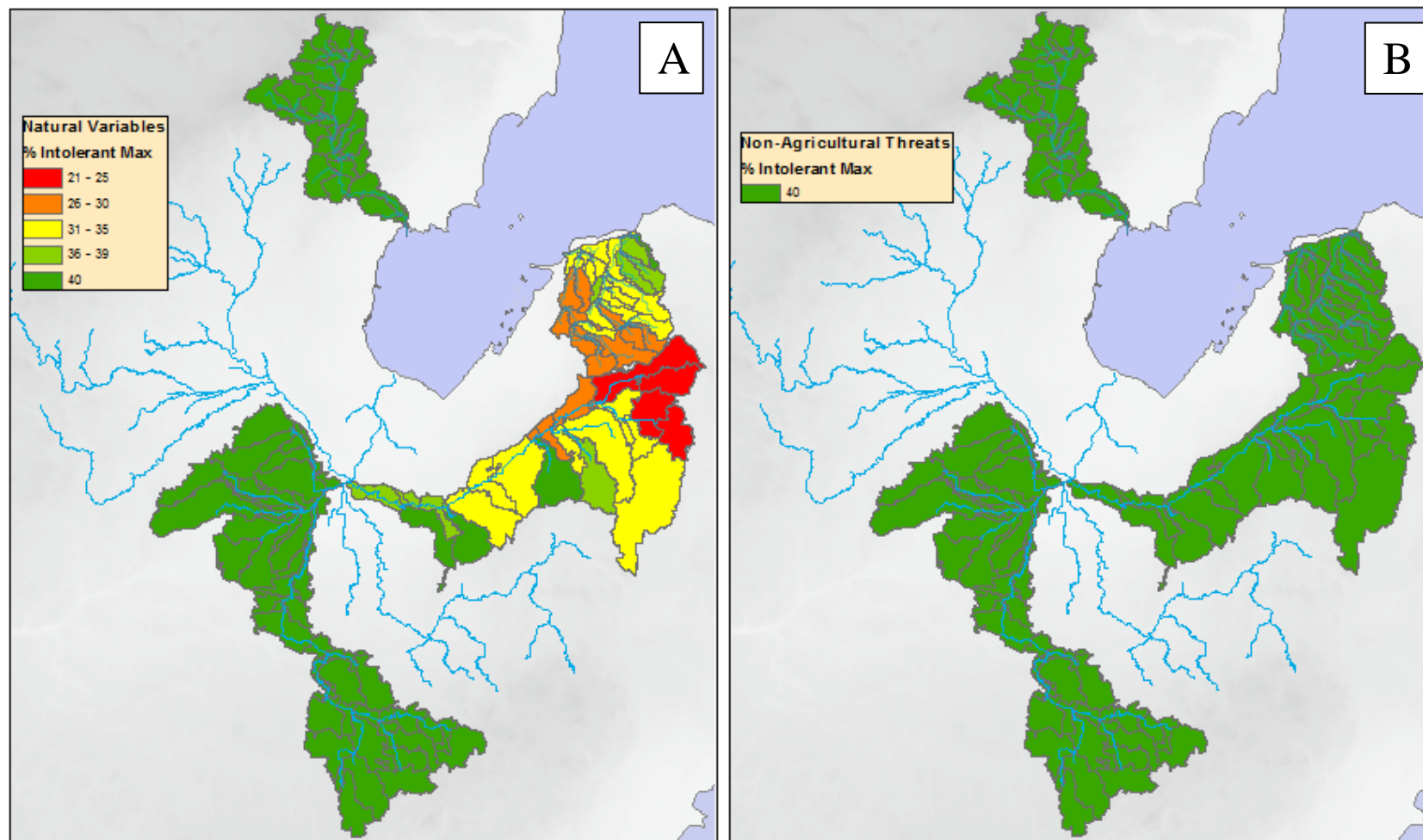


Figure 15. Maximum attainable % Intolerant fishes score for each subwatershed across the study areas based on predicted limitations due to key A) natural variables (groundwater index) and B) non-agricultural threats (no limiting non-agricultural threat was found in the analysis). A score of 40 indicates that the subwatershed is not limited by water quality variables for % Intolerant.

Table 9. Average percent (%) maximum attainable % Intolerant species across subwatersheds for each watershed.

Watershed	Current	25%	50%
Cass	76.9%	90.5%	93.3%
Shiawassee	73.5%	78.2%	84.5%
Rifle	100%	100%	100%
Pigeon-Pinnebog	4.2%	10.0%	20.6%

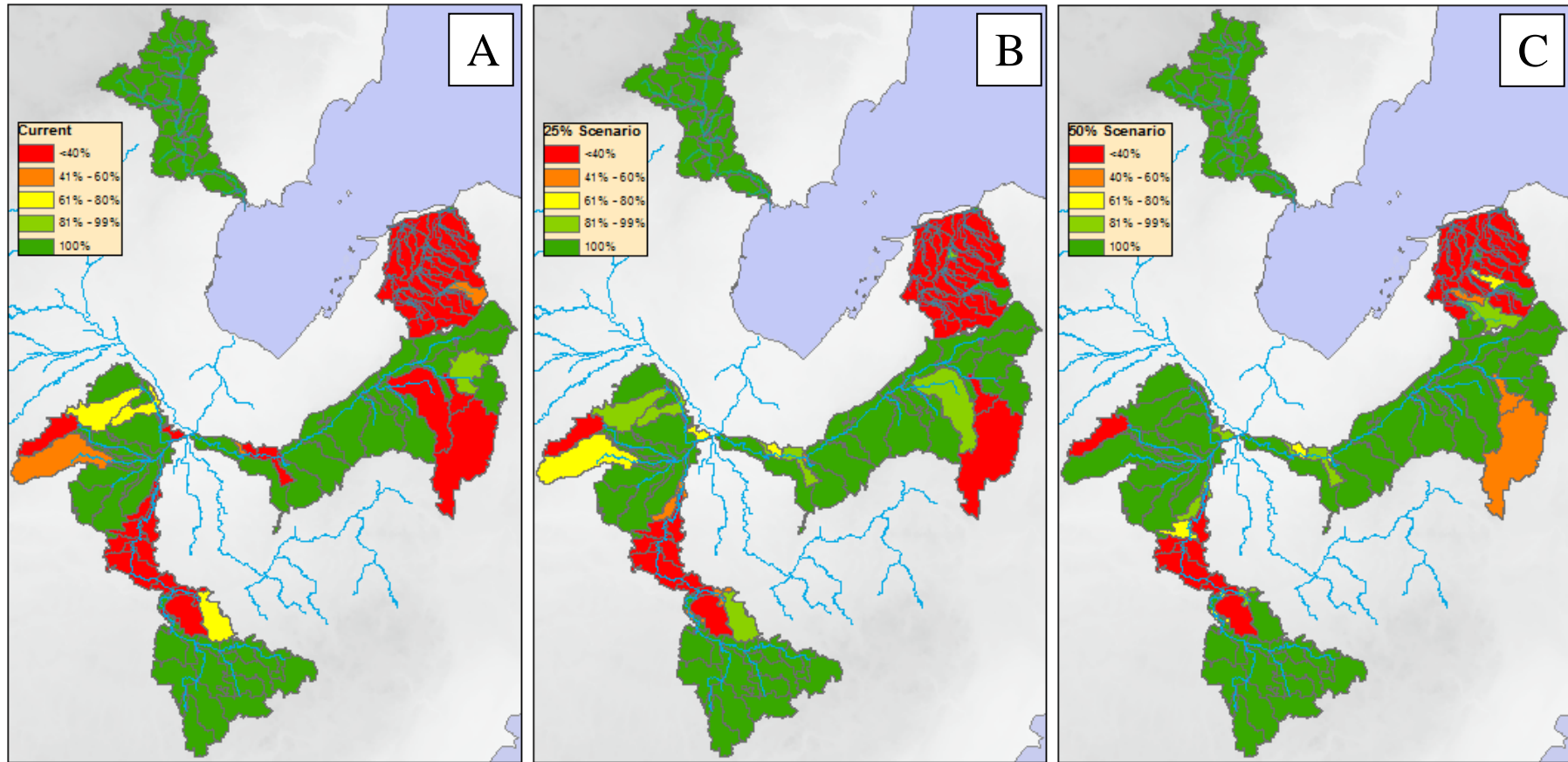


Figure 16. Percent maximum attainable % Intolerant fishes based on the most limiting water quality variable for each subwatershed across the four priority watersheds for A) current conditions, and B) 25% and C) 50% of the row crop acres in conservation practices. Subwatersheds in dark green are not limited by water quality or flow variables, while subwatersheds in orange or red are highly limited.

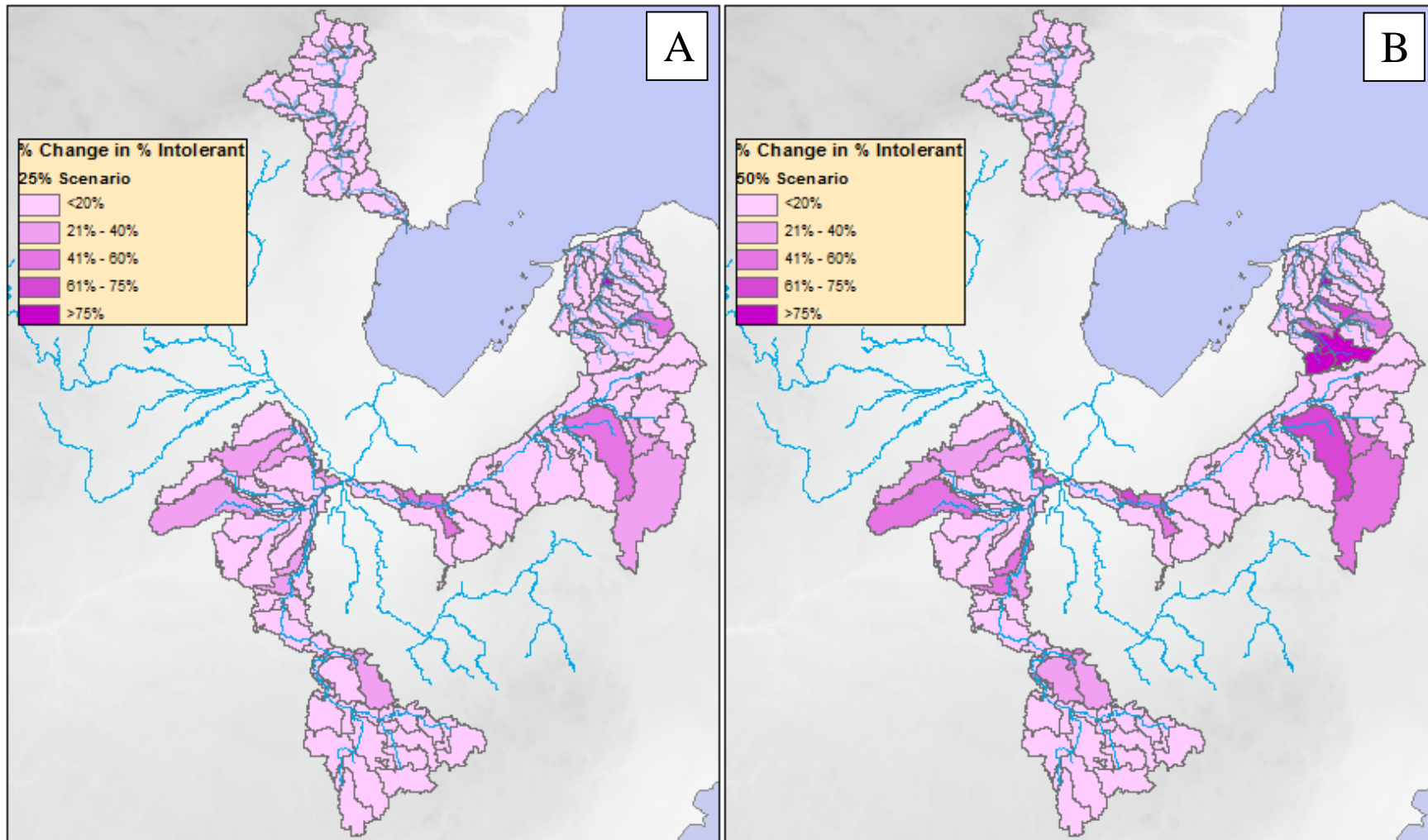


Figure 17. Change (increase) in the percent maximum attainable % Intolerant score based on the most limiting water quality or flow variable for each subwatershed across the four priority watersheds for A) 25% and B) 50% of the row crop acres in conservation practices. Subwatersheds with darker purple colors experienced greater improvement in IBI scores.

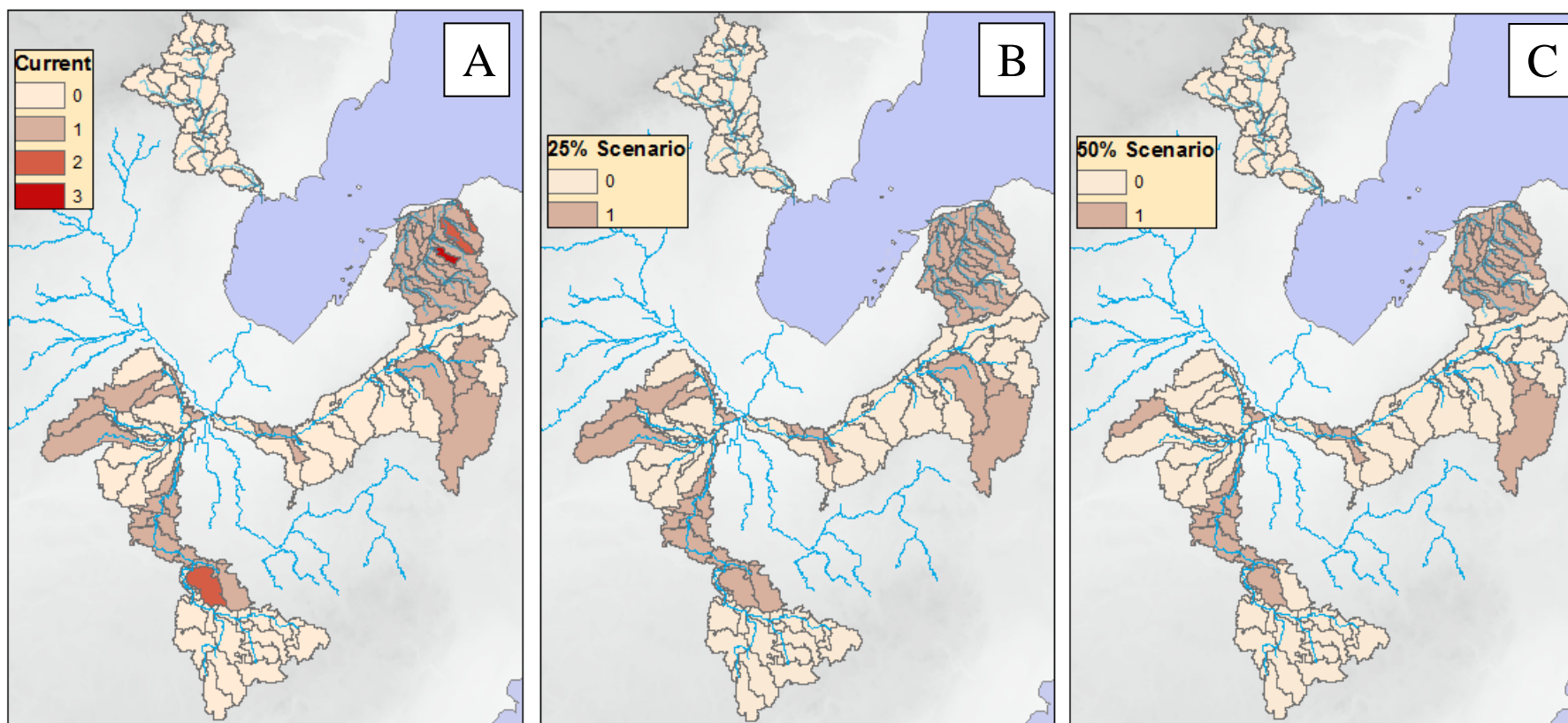


Figure 18. The number of limiting water quality variables to % Intolerant fish within each subwatershed across the four priority watersheds for A) current conditions, and B) 25% and C) 50% of the row crop acres in conservation practices.

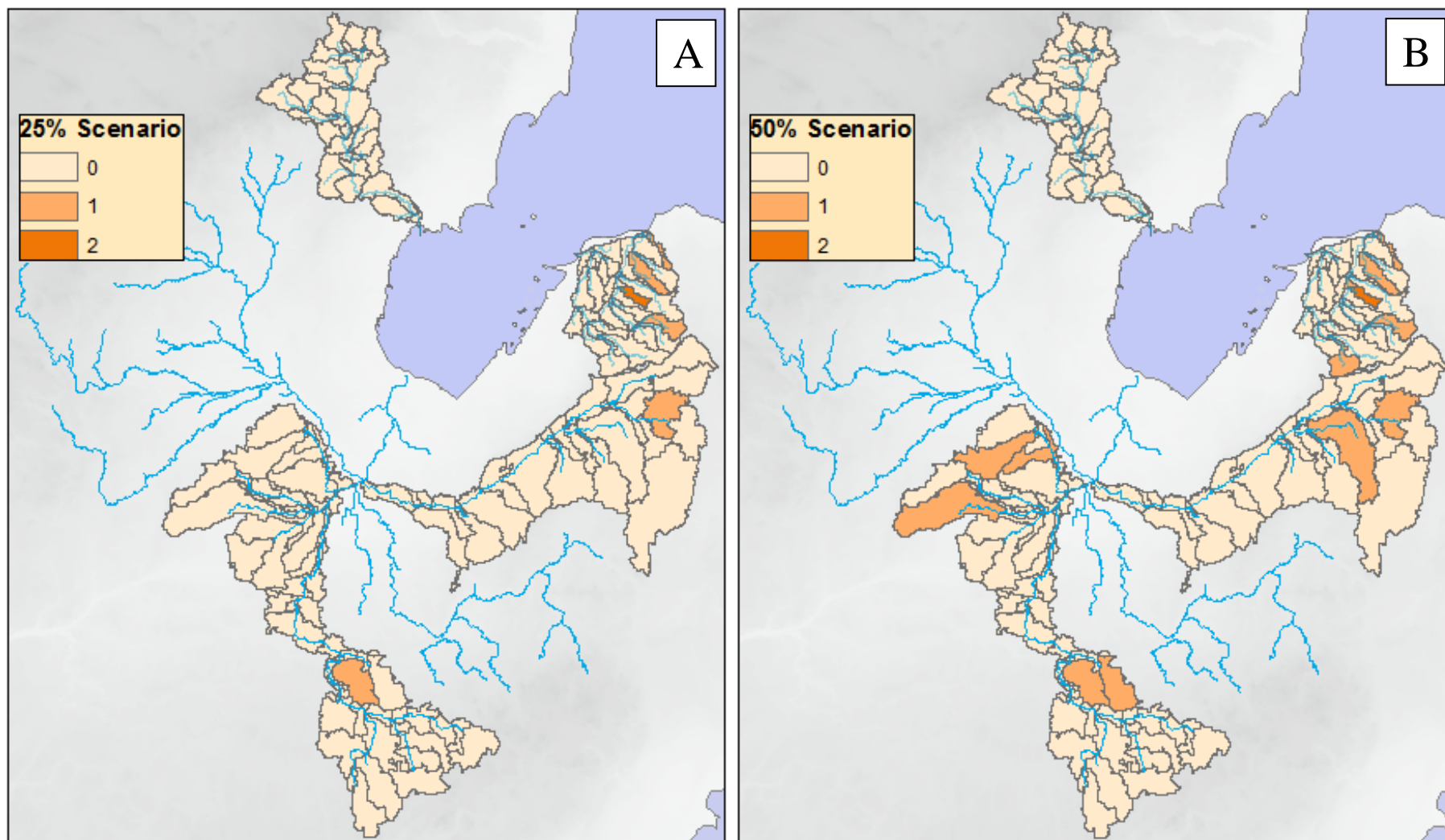


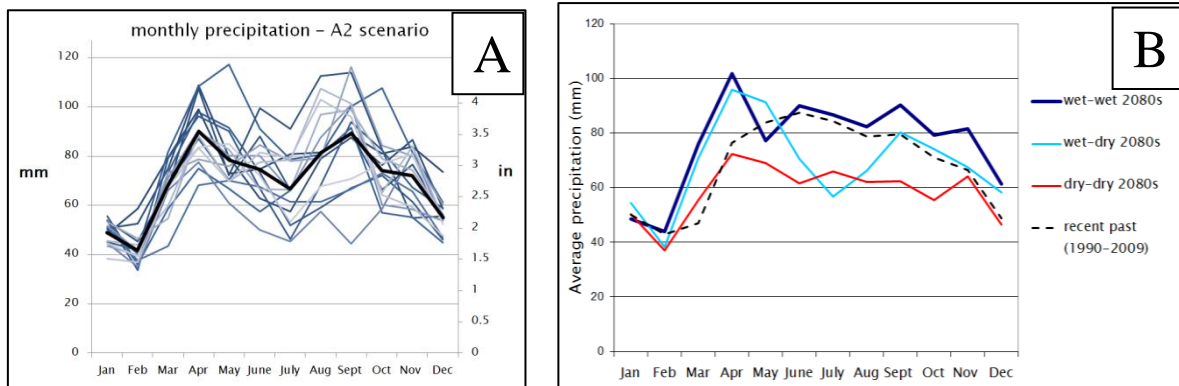
Figure 19. Decrease in the number of limiting water quality variables to % Intolerant fishes for each subwatershed across the four priority watersheds from current conditions to A) 25% and B) 50% of the row crop acres in conservation practices. Subwatersheds with darker orange colors experienced a greater decrease in limiting water quality variables.

Climate Change: How do BMP scenarios perform?

Thanks to a grant from the C. S. Mott foundation we were able to provide funding to Dr. Nejadhashemi to replicate the current, 25% and 50% conservation scenarios under 3 future climate scenarios. To do this we had the MSU team re-run the scenarios, but changed the climate inputs that are used in the SWAT model. Specifically, we used climate (temperature and precipitation) inputs that were projected for the 2080s, rather than the recent temperature and precipitation averages (1990-2009) from local climate stations used in the rest of our work. The goal of the climate change component was to have a means to evaluate how “robust” the results from our conservation scenarios were to changes in climatic conditions – is our answer to “how much is enough” likely to change dramatically as a result of changes in climate? While we realize that over the next 70 years many factors influencing these systems are likely to change in addition to climate, these runs give us some perspective on how to think in a pro-active manner about the long-term performance of these strategies.

Our approach to creating future climate scenarios was guided by our goal of using these runs to evaluate the strengths and weaknesses of our conservation strategies. It is common for modelers interested in comparing model outputs across runs for current and projected climate to focus on scenarios that compare average sets of model projections (i.e., from the 16 Global Circulation Models, GCMs, for which monthly data are readily available) from runs with higher or lower rates of temperature change (i.e., comparing high CO₂ emissions scenarios to low emissions scenarios). However, given the key role of precipitation in driving impacts in agricultural watersheds, we chose to develop an innovative approach that focused on comparing different projections for precipitation at key times of year (in addition to higher temperatures). In part, this focus on precipitation was needed, because future projections for precipitation in our region are highly variable, with different GCMs giving very different results (Figure 20A). Averaging across the sixteen seasonal patterns of precipitation suggested by these models would lead to models projecting increases in rainfall basically “cancelling out” those projecting declines.

Instead of averaging across all 16 models, we were interested in exploring how this variation in future projections might affect the performance of our “dose response” curves – in effect, changing our answer to “how much conservation is enough.” So, we developed scenarios for precipitation that focused in on the variation that is most relevant to our understanding of how BMPs work to protect fish – specifically, we focused in on how much precipitation was projected for early spring, when most run-off occurs, and summer, when low water levels can reduce fish habitat quality. So, rather than using an “average” across all of the models for the A2 (high) emissions scenario (the black line in Figure 20A), we used the three scenarios for precipitation that are shown in Figure 20B as inputs to the SWAT model. We have three scenarios we label as: Dry-Dry, Wet-Dry, and Wet-Wet, based on whether the scenarios were drier or wetter in spring-summer – the names are relative to the other models in the suite of 16, but overall the wet components of the projected precipitation curves tend to be wetter than current conditions for the most ecological important times, and dry periods tend to be drier than the data representing current conditions (see black dashed line in Figure 20B).



Figures 20 A&B. Precipitation scenarios for 2080. Figure 20A shows the projections for all 16 models, with the dark black line showing an average. In Figure 20B, we show our “customized” scenarios for testing our “how much is enough” work in Saginaw Bay. Here, each solid line represents an average of values from three global climate models that showed similar seasonal patterns under the A2 (i.e., high) carbon emission scenario. For comparison, the dashed line shows averages from the recent past.

To create the climatic datasets shown in Figure 20B, we used ClimateWizard (climatewizard.org), The Conservancy’s online portal for climate projections from the Fourth Intergovernmental Panel on Climate Change Assessment and report. We chose to use the highest emissions scenario available on the site (A2), as current observations most closely track (or exceed) this projection. Next, we explored the variation among precipitation patterns projected by the 16 GCMs for the region surrounding Saginaw Bay, and extracted monthly values for the 2080s projection endpoint (which should be interpreted as a 20 year mean centered in the 2080s). Monthly means for each model were ranked (i.e., highest mean across all models for a particular month would get a “1”), with the goal of finding sets of three models that had similar ranks across months, and allowed us to compare different magnitudes and seasonal patterns of precipitation. Given the complexity of patterns (Figure 20A), and our limitation to running three climate scenarios, we could not look at all forms of variation in the outputs, but focused in on two time periods – the early spring (when consequences of runoff can be most severe due to a lack of vegetation), and late summer, when reduced precipitation can contribute to low flows. Our original intent was to create “wet”, “average”, and “dry” spring precipitation scenarios, but we found this to be unrealistic, as models with high spring precipitation patterns had two clear patterns for the rest of the year: staying high or dropping low. An average across that variation would have masked these two opposite patterns in the climate model projections for summer conditions.

To prepare climate data for use by Dr. Najadhashemi and team, we created custom spatial data sets in ClimateWizard by selecting the three models for each scenario that showed the characteristic pattern (dry-dry, etc.), and then created an averaged spatial data layer (average of the precipitation value projection across the three models) for each month of the 2080s climate projection model output. The spatial locations for the weather stations used for the “current” climate information were overlaid on these spatial data averages, and values for each were tallied and formatted for input into SWAT. For all three climate scenarios, we used a similar procedure to extract the temperature average across all 16 models available in ClimateWizard for weather station location in the Saginaw Bay region. The SWAT modelers used a well-established procedure to convert the

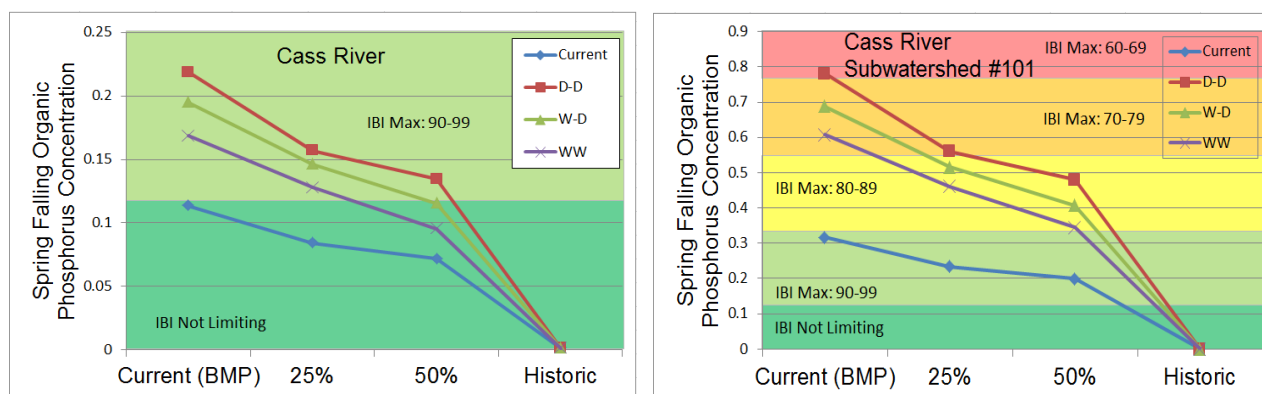
monthly averages into the daily values that the model requires. It is important to note, however, that this approach assumes that the shape of the distribution of rain events does not change with changes in monthly averages, and approaches for converting from monthly to daily values are often criticized for a lack of ability to represent extremes. So, as with any projection into the future, there are numerous uncertainties and areas for methodological improvement, and these caveats frame our interpretation and application of the climate change SWAT simulation results.

The pattern of results shown in the climate scenario outputs were complex, with many interesting relationships, and we have not fully analyzed the results of these scenarios in terms of predicted effects on water quality, flow, and biological endpoints. Here, we include results for SWAT model runs parameterized to represent current BMP conditions. The results show that under most of the future climate scenarios watershed loadings of nutrients and sediments tend to **decrease**, while in-stream concentrations tend to **increase** (Table 10). We expect that these results are due to modeled increases in the rates of evapotranspiration (recall that the climate scenarios varied in terms of precipitation, but all used 2080 temperatures from the A2 (high emissions) scenario. It appears that increases in evapotranspiration, which reduces runoff and river flows—and tends to override the increased precipitation, which we would expect to act in the opposite way.. So while overall loadings are reduced for many combinations of subwatershed and climate scenario, concentrations increase due to reduced dilution. This is an important finding since biological processes in rivers are more influenced by concentrations whereas for lentic receiving waters--here Saginaw Bay--nutrient and sediment concentrations are largely driven by tributary loads.

Table 10. Proportional changes from current conditions for water quality variables within each watershed for each of the three climate scenarios. Water quality variables include organic phosphorus (ORGP), suspended sediment (Sed), and ammonia (NH4). Each variable is reported for both gross loading from the watershed (Load) and in-stream concentrations (Conc). The box highlights how loadings tend to decrease under future climate change scenarios, while in-stream concentrations tend to increase.

Watershed	Scenario	ORGP (Load)	ORGP (Conc)	Sed (Load)	Sed (Conc)	NH4 (Load)	NH4 (Conc)
Cass	Dry-Dry No BMP	-44.2%	22.3%	-57.8%	-8.9%	-34.4%	43.5%
	Wet-Dry No BMP	-14.9%	20.6%	-31.2%	-4.5%	-4.4%	35.4%
	Wet-Wet No BMP	1.5%	8.7%	-6.8%	-0.9%	13.1%	21.1%
Shiawassee	Dry-Dry No BMP	-44.7%	13.5%	-55.4%	-10.3%	-34.1%	35.3%
	Wet-Dry No BMP	-15.7%	14.2%	-28.6%	-5.8%	-4.9%	28.9%
	Wet-Wet No BMP	1.7%	3.3%	-2.7%	-2.3%	14.9%	16.7%
Rifle	Dry-Dry No BMP	-21.0%	7.2%	-15.9%	0.5%	3.7%	40.7%
	Wet-Dry No BMP	11.2%	11.7%	27.8%	9.6%	28.8%	29.4%
	Wet-Wet No BMP	14.6%	1.6%	26.6%	8.3%	41.0%	25.0%
Pigeon/ Pinnebog	Dry-Dry No BMP	-35.5%	-1.5%	-42.6%	-6.5%	-21.9%	19.2%
	Wet-Dry No BMP	-9.5%	-2.7%	-3.8%	3.9%	6.7%	14.7%
	Wet-Wet No BMP	5.6%	-11.6%	25.5%	11.8%	21.0%	1.3%

Consequently, these results suggest that our conservation scenarios identified under recent climatic conditions could provide significantly less improvement in riverine water quality and fish community conditions, especially if the future climate is closer to the “dry-dry” or “wet-dry” scenario. The power of our approach is illustrated in the next step of how we evaluate “How much conservation is enough?” Figures 21 A & B show dose-response curves linking SWAT outputs for late-spring organic Phosphorus concentrations, to fish diversity outcomes under different conservation practice and climate change scenarios. These examples from the Cass River watershed suggest that the level of conservation practice implementation would need to increase in the future to address this stressor, and also emphasize the importance of spatial scale. The results at the larger scale (left – outlet of the Cass River) suggest that while more work would be needed to address climate change in the future, high IBI scores are still attainable. However, at the smaller scales (a subwatershed within the same system), Phosphorus appears much more limiting under projected climate scenarios, with unlimiting conditions much more difficult to attain. Further, without substantially greater conservation practice implementation, fish communities are likely to degrade considerably.



Figures 21 A (left) & B (right). Dose-response graphs showing fish IBI as a function of the spring falling organic Phosphorus concentrations predicted by SWAT model runs under different conservation practice and climate change scenarios. The climate scenarios include “current” conditions, and the dry-dry (D-D), wet-dry (W-D) and wet-wet (W-W) seasonal patterns for precipitation illustrated in Figure 20B.

In a nutshell, preliminary work to consider how “robust” our strategies are to climate change suggest that additional conservation actions would be needed to achieve the same improvements currently projected with our 25 and 50% BMP scenarios. However, these same results suggest that less conservation actions would be needed to achieve given nutrient or sediment load to Saginaw Bay (the Rifle tends to show increases in loadings, but this it is important to remember that this subwatershed has the lowest overall proportion of agriculture, so the total values associated with these percent change values are lower than the other three, and impacts to the bay are likely to be driven by changes in the more agricultural subwatersheds). It is also important to note that since we are not modeling relations of nutrient and sediment loads to biological endpoints in the Bay we cannot state that we will likely need less conservation practices to address issues like harmful algal blooms under projected future climates. There are many other factors, like water temperature and

light availability, and complex processes within the Bay that affects the occurrence and magnitude of such blooms.

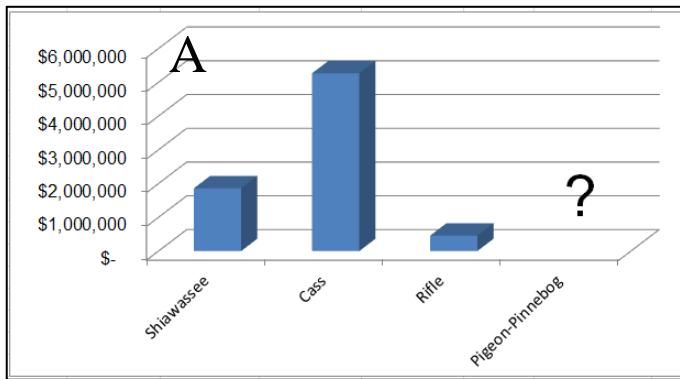
This above information is invaluable for meeting our ultimate goal of developing realistic sets of performance goals for these priority subwatersheds. However, there are many difficult decisions that must be made by our Advisory Panel and other key partners based on a careful and thorough evaluation of our results and other relevant information. Our new Saginaw Bay Director, Ms. Mary Fales, has been presenting the results of our work to many key partners across Saginaw Bay and the larger Great Lakes. As we detail below in the results for Tasks 1g, h, and i, the response to our work has been very positive and is already being used in many innovative ways by many partners.

1f. *Generate cost and time estimates for each scenario.*

Based on the dose-response relationships presented in Figure 6, we estimated that the stream segments at the outlets of the Cass, Rifle, and Shiawassee River watersheds would become no longer limiting to the fish community with 18, 18, and 5% of the row-crop lands in theirs treated with our selection of conservation practices, respectively. Even under the 50% scenario the outlet of the Pigeon/Pinnebog was predicted to still be limiting the fish community. Based on the 2012 MI statewide practice costs data the estimated costs to achieve these results at each outlet, were \$458,000 for the Rifle River, \$1.9M for the Shiawassee and \$5.3 M for the Cass (Figure 22A). The sum of these estimated installation costs is \$7.7M, which based on discussions with our local partners is a relatively high cost compared to past investments in these watersheds, but not unreasonable.

The total estimated installation costs for our 25% and 50% scenarios were ~\$22M and \$44M, respectively and varied considerably among the four watersheds due to the different amount of row-crop agriculture. These costs are significantly more than the estimated \$7.7M needed to achieve unlimiting conditions at the outlets of the Cass, Rifle and Shiawassee River watersheds. However, as the chart in Figure 23 and corresponding maps for IBI in Figures 9 and 12 all show in all but the Rifle River watershed, fish communities in many of the subwatersheds would still be limited even under the 50% conservation scenario.

A. Cost for Outlet Conservation



B. Total Cost for Scenarios

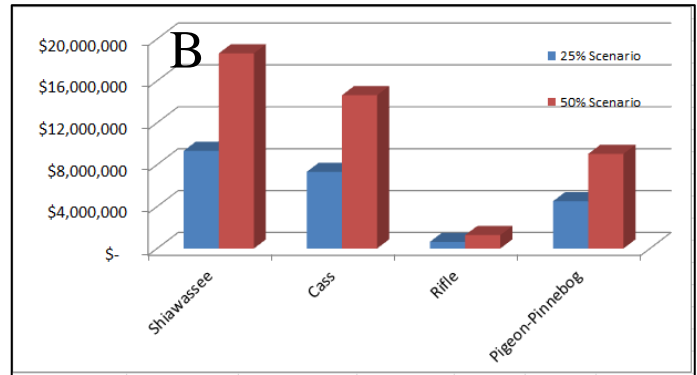


Figure 22. Estimated implementation costs (in millions of dollars) needed for our selected set of conservation practices to improve water quality and flow conditions to the point that they no longer limit the fish community A) at the outlet of each watershed and B) total costs for the 25% and 50% scenarios across each watershed. Predictions suggest we were unable to achieve unlimited conditions in the Pigeon-Pinnebog even under the 50% scenario, so the costs for achieving such conditions is unknown.

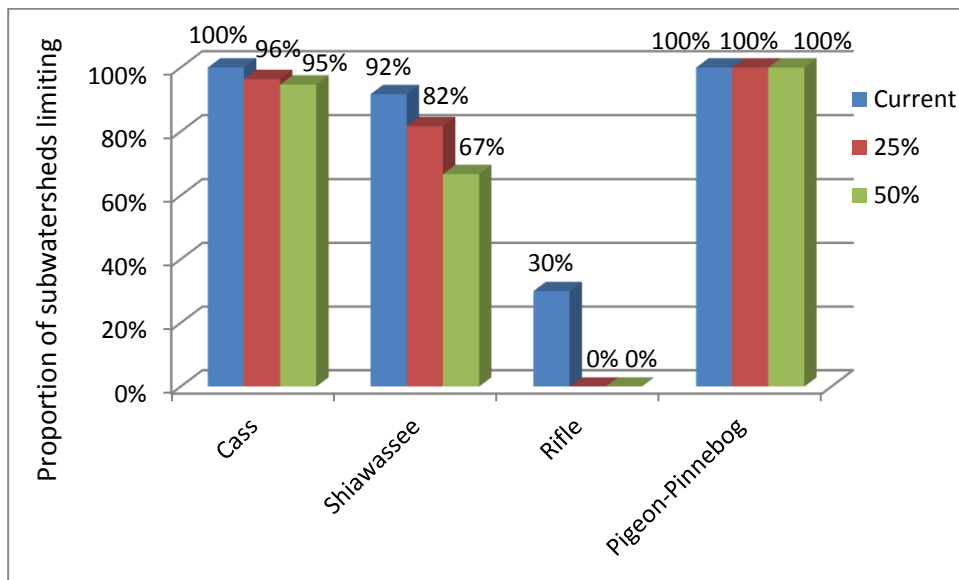


Figure 23. Proportion of subwatersheds where water quality is predicted to be limiting the fish community (i.e., IBI metric) within each watershed under current conditions and the 25% and 50% conservation scenarios.

1g. Work with the Advisory Panel to compare and contrast the conservation scenarios.

In July 2012 TNC hired Mary Fales as our Saginaw Bay Watershed Project Director, thanks to support from the C.S. Mott Foundation. Since that time Mary's work has focused on;

- a) understanding how the conservation scenarios affects each of the priority watersheds,
- b) gather available documentation about watershed planning or implementation efforts already underway in each of the priority watersheds,
- c) make first time contacts in each of the priority watersheds among members of the Advisory Panel and other partnering organizations including conservation districts, land conservancies, commodity groups, environmental organizations and other key partners and
- d) help our partnering organizations to understand the implications of the CEAP conservation scenario modeling and solicit their feedback.

Mary has already made progress on these tasks and has met with at least one partnering organization in each of the priority subwatersheds in addition to at least four individuals who participated on the original meeting of the Advisory Panel. Mary Fales has also worked with many additional stakeholders to broaden the scope and impact of the conservation scenario planning and has started to build broad based partnerships for increasing the potential for this work to influence conservation work on the ground. They include:

- Charlie Bauer, Thad Cleary, Bob Day, Peter Vincent, Rob Zbiciak, MI DEQ
- Abby Ertel and Garrett Noyes from Huron Pines, Rifle River Watershed
- Mike Kelly, Saginaw Bay Watershed Initiative Network, Conservation Fund
- Steve Shine, Michigan Department of Agriculture
- Greg and Jeanette Renn, Huron Conservation District, Pigeon/Pinnebog Rivers
- Tony Newman, Shiawassee County Drain Commissioner
- Joseph Rivet, Bay County Drain Commissioner
- Joe Toth, Bob Zeilinger and Bob Zehnder, Cass River Greenway
- Sara McDonnell, Jonathan Jarosz of U of M Flint Outreach Center (Cass River)
- Russ Beaubien, Spicer Group (Cass River)
- Mark Wykoff, MSU Land Policy Institute
- Dr. Don Uzarski, Central Michigan University
- Jerry Grigar, NRCS State Agronomist
- Zak Branigan and Trevor Edmonds, Saginaw Basin Land Conservancy
- Tim Boring, Research Director, Michigan Soybean Promotion Committee
- Joe Kautz, Sanilac Conservation District
- Jim Kratz, Tuscola Conservation District
- Jim Hazelman and Michelle VanderHaar, U.S Fish and Wildlife Service
- Amy Braun, Sustainability Manager, Kelloggs Company
- Albert Jones, Assistant State Conservationist, USDA-NRCS
- Garry Lee, State Conservationist, USDA-NRCS
- Lori Phalen, Michigan Association of Conservation Districts
- Mike Schneider, Great Lakes Commission
- Jon Bartholic, MSU Institute of Water Resources
- Michelle Selzer, Office of the Great Lakes. MDEQ

- 1h. *Use selected scenarios to develop more specific blueprints and schedules of conservation action.*

The ultimate purpose of this work is to influence the future implementation of conservation practices in agricultural landscapes by answering basic questions about the ability of varying levels of implementation to affect the very ecological outcomes we seek. The scientific analysis, models and recommendations developed by this project are important new advancements in science that have never before been available to resource managers in the Saginaw Bay Watershed. Therefore, an important aspect of this project was to communicate the science and recommendations to the broader Saginaw Bay Watershed Stakeholders (as described/listed above) and more importantly, seek ways to integrate the recommendations and strategies into real-time planning efforts in the four focus subwatersheds in this study. It was the main responsibility of Mary Fales, Saginaw Bay Watershed Project Director to complete this task.

Rifle River

The Rifle River is a direct tributary to the northwest side of Saginaw Bay. The Rifle River Watershed spans 396 square miles and while mostly forested, is approximately 21% in agricultural land use. The CEAP model results suggest that the health of the fish community in the Rifle River, measured by the IBI score, is predominantly limited by local geology (natural threat) and only somewhat limited by local livestock activity (non-agricultural threat). Figure 8 indicates that the proportion of fine textured end moraines in certain upper to mid subwatersheds of the Rifle River (Figure 8a) show the most limiting effect on local fish communities while average cattle density (Figure 8b) may only have a slight effect on fish health. Appropriately, summer sediment levels was the only water quality variable significant for fish community health at the outlet of the Rifle River (Figure 6). All other WQ variables were currently shown to be non-limiting to fish community health (at the river's outlet). However, early spring levels of phosphorus are limiting fish health in two subwatersheds in the upper reaches of the Rifle (Figure 11).

Currently, the local organization that is managing watershed management activities in the Rifle River is Huron Pines. Huron Pines is currently administering a GLRI grant to support activities related to the Rifle River Watershed Project which include on the ground restoration projects, public education and awareness efforts and developing an EPA approved watershed management plan. Huron Pines has invited TNC staff to participate on the planning/advisory committee that will help develop the plan and TNC's role will be to help Huron Pines understand and incorporate the CEAP data and recommendations into the plan.

Shiawassee River

The Shiawassee River is a tributary to the Saginaw River which eventually empties into Saginaw Bay. The Shiawassee River Watershed spans 1,160 square miles and while an important downstream part of the watershed is known for the National Wildlife Refuge, the watershed is predominantly agricultural which covers 88% of its land area. The CEAP model results suggest that the health of the fish community at the outlet of the Shiawassee River, measured by the IBI score, is predominantly limited by levels of late spring phosphorus and summer sediment (Figure 6). All other WQ variables were currently shown to be non-limiting to fish community health (at

the river's outlet). However, early spring levels of phosphorus are limiting fish health in many areas in both downstream and upstream areas of the watershed, nitrates are limiting in middle portions of the watershed, late spring phosphorus is limiting in upper reaches of the watershed along with specific areas of concern for summer sediment and fall and winter phosphorus (Figure 11). By examining the dose response curves the outlet of the Shiawassee River becomes no longer limiting to fish for all water quality variables for the 25% implementation scenario (Figures 6 and 9).

Review of the model results for the Shiawassee River Watershed demonstrates just how complex of a picture the model can present. The dose response curves typically show the scenario results for the outlet of the river but examining the situation at the subwatershed level can reveal numerous levels of complexity. TNC's engagement in the Shiawassee River Watershed has unfolded in two main ways in response to varying levels of partnership opportunities.

A close partner of TNC's, the MSU Institute of Water Resource has initiated the Michigan Natural Resources Working Group (NRWG) which is a partnership of federal, state and local agencies and organizations with an interest in conserving Michigan's natural resources. The group has identified the Shiawassee River Watershed as a common geography in which they would like to collectively and collaboratively develop and implement outcome based strategies to address agricultural conservation. Mary Fales is a member of the team and TNC staff is integral to facilitating group meetings. The NRWG appears to moving in a direction that would lead them to consider implementing the framework of CEAP and the model recommendations presented by this project to move group initiatives forward in the Shiawassee River Watershed, especially in regards to further expansion of the Michigan Agricultural Environmental Assurance Program (MAEAP).

Additionally, TNC has partnered with the Saginaw Conservation District on a grant proposal to the Michigan Department of Environmental Quality for Section 319 funding to develop a watershed management plan for the Bad River, a tributary to the Shiawassee River. The Bad River flows into the Shiawassee near its downstream end, just upstream of where it enters the Saginaw River. Review of the CEAP results indicate that implementation of the 25% scenario in the Bad River could improve the health of the fish community by 6-10% (by measurement of the IBI score) and 16-20% in the 50% implementation scenario (Figure 10). We have proposed that the CEAP data be used to aid in developing a critical area analysis under that plan and that the groundwater, sediment and nutrient calculators (being developed separately under private funding from the C.S. Mott Foundation Grant) be utilized as part of the implementation strategy in that watershed.

Cass River

The Cass River is also a tributary to the Saginaw River and enters the river just downstream from the Shiawassee River. The Cass River Watershed spans 908 square miles and is dominated by agricultural land use (59%) in the upper reaches and forested and natural land cover (37%) in the middle to lower regions. The CEAP model results suggest that the health of the fish community at the outlet of the Cass River, measured by the IBI score, is predominantly limited by levels of late spring phosphorus and summer phosphorus (Figure 6). All other WQ variables were currently shown to be non-limiting to fish community health (at the river's outlet). However, in the upper reaches of the Cass River Watershed where agricultural land use is most intense, early spring, fall and winter levels of phosphorus and summer sediment are limiting fish health (Figure 11). In the

middle and lower portions of the watershed that are more forested, summer levels of phosphorus and sediment, and nitrate appear to be limiting fish health (Figure 11). By examining the dose response curves, the outlet of the Cass River becomes no longer limiting to fish for all water quality variables for the 25% implementation scenario and all water quality variables fall safely within the non-limiting range in the 50% scenario (Figure 6). However, even under the 25% and 50% implementation scenario, there still exist water quality variables that limit the health of the local fish community in the uppermost areas of the watershed that are mostly agricultural (Figure 11).

TNC's challenge was to consolidate the myriad of data layers produced by the CEAP model and experiment with putting the model recommendations into practice in a real-world situation in partnership with the organizations and individuals who typically deliver technical assistance to local farmers and work to make regional and local conservation management decisions. Working through a partnership scoping approach, TNC identified the Tuscola and Sanilac Conservation Districts as viable partners who were eager to commit to this project. These conservation districts are located in the upper reaches of the Cass River Watershed in a predominantly agricultural area. The partners were not members of the original Saginaw Bay Advisory Council and therefore had no prior knowledge of the CEAP project or the "How Much is Enough?" concept. To their advantage, the districts were active in the region's efforts to develop an EPA approved Watershed Management Plan and were experienced in working with the region's farmers.

TNC staff learned via development of the pilot project that the local conservation districts expected to be involved in understanding and using the CEAP results to make local conservation management decisions. As described above, the CEAP model output and results offer a myriad of informational layers that can be interpreted in a variety of ways. TNC staff worked with our partners and spent a considerable amount of time debating how the information could or should be used to advance strategic conservation in agricultural watersheds. The following questions are a few examples of some of the difficult questions we have discussed and considered both internally and with external partners as we have begun to use the results to help set realistic goals and guide strategic conservation to achieve them.

1. *Should the ultimate goal be to use the model results to identify and focus on watersheds A) only where we can achieve non-limiting conditions or B) where we can achieve the largest improvements in the local fish community?*
 - If we choose A as our guiding principle, then our IBI analysis results for the overall watersheds (Figure 6) suggest we should only work in the Cass, Rifle, and Shiawassee watersheds and not in the Pigeon/Pinnebog River Watershed because it would be unlikely that those watersheds would reach conditions that would not limit fish community health. However, if we choose B as our guiding principle then these same results indicate that conservation work should be targeted to the Pigeon/Pinnebog River Watershed because our models predict that we can achieve the largest improvements in fish community health in this watershed, but conditions will likely still be limiting.

2. *Should watersheds be prioritized by their relative cost to achieve non-limiting conditions?*
 - If so, then our cost analyses presented in Figure 22A suggests we should work first in the Rifle, then the Shiawassee, Cass, and lastly the Pigeon/Pinnebog.
 3. *Should conservation action and related funding goals be driven by watershed or subwatershed results?*
 - This question has been a key discussion item with many partners and one that requires answers at national levels. As we presented above in the results above under Task 1f, the estimated implementation costs of ~\$7.7M to achieve unlimiting conditions for stream segments at the outlets of the Cass, Rifle and Shiawassee River Watersheds seem achievable to our partners, but would require significant increases above current restoration investments. However, the more detailed subwatershed cost-benefit analyses that predict fish communities in many of the subwatersheds would still be limited under the 50% conservation scenario and overall estimated installation cost of around \$44M, is staggering but not surprising to our partners.
- 1i. *Work through the Advisory Panel to develop appropriate outreach and innovative solutions for carrying out the recommendations from task 1h.*

TNC staff worked to develop the elements of the pilot project informally via communication with the various partners as described in Task 1G. Once the specific partners were identified as described in Task 1H, Mary Fales initiated specific meetings with key partners to solicit input, suggestions and feedback on how to implement the pilot project and interpret the CEAP recommendations in the Cass River Watershed. Those key partners included:

- Charlie Bauer, Thad Cleary, Pete Vincent and Rob Zbiciak, MDEQ
- Sara McDonnell, U of M Flint Outreach Center
- Joe Toth, Bob Zeilinger and Bob Zehnder, Cass River Greenway
- Jim Hazelman and Michelle VanderHaar, U.S Fish and Wildlife Service
- Joe Kautz, Sanilac Conservation District
- Jim Kratz, Tuscola Conservation District

As presented above, there was an abundant amount of information available for the Cass River Watershed upon which to make conservation management decisions. TNC secured private funding from the C.S. Mott Foundation to operationalize the management recommendations by supporting the work of a full time conservation technician in Sanilac and Tuscola Counties.

Ultimately, the key stakeholders agreed that the value of the CEAP model results is in helping conservation managers

- 1) set realistic expectations for ecological outcomes,
- 2) understand the level of investment and implementation needed to achieve those outcomes and
- 3) provide information that will help locate areas where conservation practices will have the most impact.

In the Cass River Watershed Pilot Project, the team members now understand:

- 1) that the fish community is expected to improve the most (as measured by the IBI score) in the upper parts of the watershed and that water quality conditions will likely become no longer limiting to the health of the local fish community at the river outlet and at points along the lower and mid sections of the river,
- 2) That with intense targeting they may be able to reach desired conditions well before the 25% implementation scenario, and
- 3) That using a combination of Figures 7, 9, and 10 should provide the best guidance about where to target best management practices.

The end result of the planning phase of the project is that the partners have decided to target their efforts in seven subwatersheds of the Upper Cass River Watershed (Figure 24). These 7 subwatersheds include approximately 116, 000 acres of row crop agriculture. Technicians at the partnering conservation districts will actively promote and target a suite of best management practices in these areas with the ultimate goal of achieve the 25% implementation scenario.

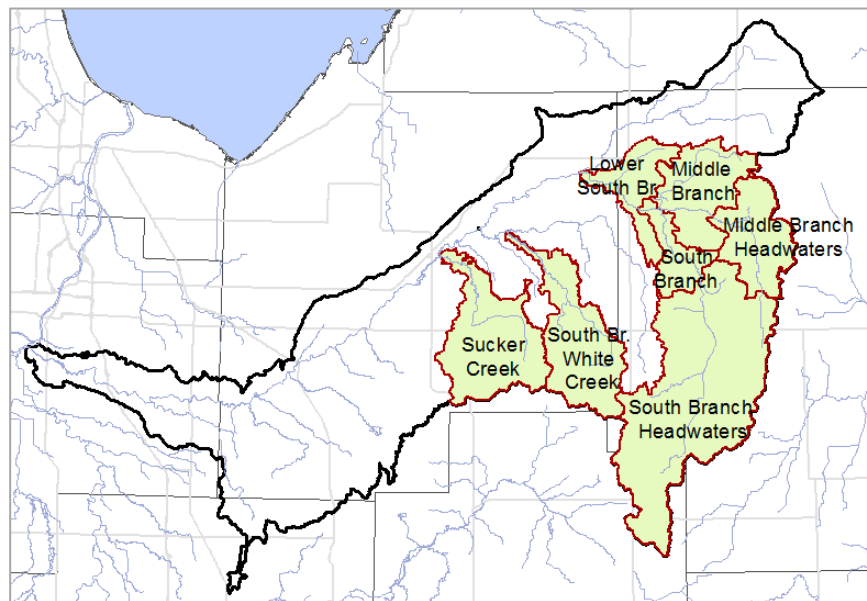


Figure 24. Seven focal subwatersheds of the Cass River Watershed Pilot project where TNC is working with local conservation districts to apply the results of the Great Lakes CEAP and related decision tools to help set performance goals and guide strategic conservation.

Objective 2 Introduction

The Conservation Effects Assessment Project (CEAP) was initiated by the USDA Natural Resource Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES) to help inform society of the benefits of USDA conservation program funding. The original goal of CEAP was to establish a scientific understanding and methodology for estimating environmental benefits and effects of conservation practices on agricultural landscapes at national, regional, and watershed scale (Maresch et al. 2008). In 2005, USDA engaged the Soil and Water Conservation Society (SWCS) to assemble a panel of academics and conservation community leaders (the SWCS CEAP Blue Ribbon Panel). This panel was charged with providing recommendations on 1. how to ensure that CEAP is and remains relevant, responsive, and credible and 2. how to ensure that CEAP products have utility for program managers, policy makers, and the conservation community. While the panel strongly endorsed CEAP's overarching goal, it recommended that the CEAP plan be expanded and adjusted: "CEAP must change direction to become the coherent, science-based assessment and evaluation system that is critically needed" (SWCS 2006).

The goal of CEAP is to improve efficacy of conservation practices and programs by providing the science and education needed to enrich conservation planning, implementation, management decisions, and policy. Three principal coordinated activities guide efforts to meet the goal of CEAP: (1) research to advance our knowledge of linkages between conservation practices and environmental quality, (2) retrospective assessments of conservation benefits and (3) forecasting costs and benefits of practices to a broader suite of ecosystem endpoints to enhance conservation planning and improve the effectiveness and efficiency of conservation programs. The research and assessment activities will continue to address the effects of conservation on four components: Croplands, Wetlands, Wildlife, and Grazing lands (Duriancik et al. 2008). However, to work toward establishing a truly integrated and operational framework for assessing, reporting, and forecasting benefits to the full suite of ecosystem services affected by USDA conservation programs, CEAP must seek to integrate the research and assessment efforts across these four components (Maresch et al. 2008).

The Wildlife component of CEAP took steps to facilitate integration with the Cropland component when it launched Phase 1 of our Great Lakes CEAP project in 2008. The Cropland component of CEAP conducts regional retrospective assessments of the benefits of conservation practices to water quality using SWAT and other related models. So, two overarching questions of Phase 1 of our project were a) could we develop a fine-resolution SWAT model across a large geographic region and 2) would the predicted water quality and quantity outputs from SWAT exhibit significant and meaningful threshold and ceiling relations to biological endpoints?

As detailed by Sowa et al. (2011) and Einheuser et al. (2012), the answer to both of these questions were—Yes. So, with these answers in hand we added objective 2 to Phase 2 of the Great Lakes CEAP project which was to; ***help foster integration of the Wildlife and Cropland components of CEAP through the modeling and assessment process established by the Great Lakes CEAP project.***

A series of four interrelated tasks, listed below, were established to accomplish objective 2. For this section of the report we present the methods and results together for each task.

Objective 2 Major Tasks

- 2a. Establish a core team including representatives of TNC, CEAP Cropland Component modelers, and CEAP Wildlife and Cropland Component leadership.
- 2b. Organize and host meetings with representatives of the core team to foster linkages between the Wildlife and Cropland components of CEAP that build upon the Great Lakes CEAP project.
- 2c. From 2b identify specific short and long-term opportunities and action steps for coordination and collaboration to facilitate integration of the Wildlife and Cropland components of CEAP
- 2d. From 2c, identify opportunities and make recommendations for long term coordination and collaboration among the Wildlife and Cropland components of CEAP that would lead to the incorporation of freshwater biological endpoints into the assessment efforts of the Cropland component of CEAP.

Objective 2 Methods and Results for Each Task

- 2a. *Establish a core team including representatives of TNC, CEAP Cropland Component modelers, and CEAP Wildlife and Cropland Component leadership.*

In May of 2011 we established an initial core team consisting of 11 representatives from TNC, but this list was significantly increased as a result of a meeting held in Temple, TX in October 2011. The team eventually grew to 19 members by April of 2012, when the new Western Lake Erie Basin (WLEB) CEAP project was launched (Table 11). This team has remained fairly stable since then and serves as the overall project team for the WLEB CEAP project.

Table 11. Core team members for Western Lake Erie CEAP project and their affiliations

NRCS CEAP Staff (NRCS headquarters, Beltsville, MD)

Michele Laur, Director, Resource Inventory and Assessment Division (RIAD)

Daryl Lund, Branch Chief, Natural Resources Analysis Team

Charles Rewa, National Assessment Lead, CEAP Wildlife Component

NRCS & ARS CEAP Staff (Grassland Soil and Water Research Laboratory, Temple, TX):

Lee Norfleet, NRCS Soil Scientist, RIAD

Mari-Vaughn Johnson, NRCS Research Agronomist, RIAD

Jeff Arnold; Supervisory Agricultural Engineer, USDA ARS

Mike White; Agricultural Engineer, USDA ARS

Texas A&M Staff

Raghavan Srinivasan, Prof. and Director of the Spatial Sciences Lab

TNC Staff:

Gust Annis, Research Specialist (MI TNC)

Matt Herbert, Aquatic Ecologist, Lead Analyst for Great Lakes CEAP (MI TNC)

¹John Legge, Conservation Dir., Great Lakes Project Watershed Strategy Lead (MI TNC)

Scott Sowa, Director of Science, Project Manager for Great Lakes CEAP (MI TNC)

Sagar Mysorekar, GIS Manager (MI TNC)

Carrie Volmer-Sanders, Western Lake Erie Basin Director (IN TNC)

Bill Stanley, Assistant State Director (OH TNC)

Anthony Sasson, Program Director/Aquatic Ecologist (OH TNC)

August Froelich, GIS Manager (OH TNC)

Ohio Sea Grant and Ohio State University

Jeffrey Reutter, Director, OH Sea Grant, Stone Laboratory, Center for Lake Erie Area Research,
Great Lakes Aquatic Ecosystem Research Consortium

Stuart Ludsins, Assistant Professor, Dept. of Evolution, Ecology, and Organism Biology

University of Missouri:

*Jeff Fore, PhD Student who led the Missouri River Basin CEAP project

¹John Legge is no longer working on the project team

²Jeff Fore is now with the Tennessee Chapter of TNC

- 2b. *Organize and host meetings with representatives of the core team to foster linkages between the Wildlife and Cropland components of CEAP that build upon the Great Lakes CEAP project.*

We held a video conference on May 24, 2011 and another informal meeting on July 18, 2011 at the annual SWCS meeting in Washington, DC. The agenda and notes from the May 24th meeting were attached as an addendum to our July 2011 quarterly report. We also held a 2 day meeting of the core team on October 3-4, 2011 in Temple, TX. The purpose of this meeting was to brainstorm on how we could most effectively foster linkages between the Wildlife and Cropland components of CEAP that build upon the Great Lakes CEAP project.

- 2c. *From 2b identify specific short and long-term opportunities and action steps for coordination and collaboration to facilitate integration of the Wildlife and Cropland components of CEAP*

During our meeting in Temple, TX the core team identified the best way to foster linkages between the Wildlife and Cropland components of CEAP that build upon this project was through a truly collaborative project across all of the core team members. So, at the meeting the core team developed an outline for a pilot project in Western Lake Erie Basin that required formal collaboration of TNC staff from IN, MI, and OH; NRCS staff working on the CEAP Wildlife and Cropland components, and ARS staff working on the CEAP Cropland component. It also identified key partners for leading the ecological modeling component of the project and helping with local outreach. Immediately after this meeting the core team started developing a detailed work plan and budget for the WLEB CEAP project that added roles for Ohio State University (ecological modeling) and Ohio Sea Grant (outreach) staff listed in Table 11.

In March 2012 we completed an integrated proposal and 3 year work plan for the WLEB CEAP project. This overall project proposal was submitted as an attachment to our April 2012 quarterly report. This proposal has led to a complimentary set of cooperative (Agreement #: 68-7482-12-504) and interagency agreements between NRCS and TNC, OSU, and ARS. The kickoff webinar for this project was held May 16, 2012 and included 10 presentations and over 50 participants from across the Great Lakes and the nation. A copy of the agenda for this meeting was submitted as an appendix with our July 2012 quarterly report. Since that time the overall and individual project teams continue to meet regularly and are staying on schedule for an April 2015 completion.

- 2d. *From 2c, identify opportunities and make recommendations for long term coordination and collaboration among the Wildlife and Cropland components of CEAP that would lead to the incorporation of freshwater biological endpoints into the assessment efforts of the Cropland component of CEAP.*

This task is continuing to be worked on by the overall WLEB CEAP Project Team as answers to these questions are a primary focus of that project.

DISCUSSION

Our unique approach, of relating fish community metrics to instream water quality and flow conditions predicted by SWAT, is a compliment not a replacement for the large body of work that has established similar empirical relations between these variables using ambient monitoring and other data, for the purpose of establishing water quality and biological criteria. (Karr 1981; Lyons 1996; Wang et al. 2006; Weigel and Robertson 2007, Miltner 2010, Dodds et al. 2010). This existing body of work is critical in that the empirical relations of field data are more accurate than our secondary predictions and also provide critical ground truthing for our work. More important is the fact that the entire approach of the Great Lakes CEAP project is dependent on large quantities of high quality weather, flow, water quality and biological data that have been collected by state and federal resource management agencies. It is our hope that the benefits of our work will help demonstrate the utility and importance of these long-term monitoring data and even help expand and improve existing programs. Finally, this existing body of work has helped us recognize the need for outcome-based rather than activity based conservation. We certainly need to move beyond conservation efforts being guided only by resource input (e.g., funding) and conservation action goals (e.g., acres of practices). However, these goals are still very important because there are often significant lag times between the implementation of conservation actions and water quality and biological responses (Meals et al. 2010). So, being able to set and track progress toward conservation action goals that are linked to ecological outcomes is critical for guiding strategic conservation in a sustained manner. It is our ability to make this added linkage of ecological conditions to conservation actions and also costs, where our approach expands upon these previous efforts and which provides a wide array of possible benefits for significantly advancing the restoration of streams in agricultural landscapes.

Ecological goals must be meaningful and realistic, particularly with regard to the cost to achieve them. For several decades we have been establishing water quality and biological criteria to help achieve the goals of the Clean Water Act (Karr et al. 1986; Weigel and Robertson 2007). However, we never answer what the cost will be to achieve these criteria (i.e., goals). Without such cost estimates how can we be certain if these goals are realistic given our current restoration investments and strategies or societies willingness to absorb significant cost increases? Our work provides the first science-based estimates of the scope of the problem we face in terms the costs for restoring fish communities in four watersheds of Saginaw Bay. By establishing relations across more levels of the performance pyramid we were able to assess ecological benefits and costs in a comprehensive manner across large regions and at different spatial grains. These additional relations allowed us to answer the ever present and complex “How Much is Enough?” question from many perspectives which is critical to setting realistic sets of performance goals. As our results showed setting related sets of realistic performance goals is not simple even with the necessary information in hand, because it depends on a reciprocal assessment of how you define your desired outcomes and the resulting answer to “How Much?” conservation action will be required and how much will it cost?

Our unique approach of linking ecological outcomes to conservation actions and associated costs provides decision makers with a wealth of information to answer important questions. However, even with this information in hand there are no easy answers. But this is really the essence of conservation...we are usually faced with difficult decisions that involve trade-offs among places and things we value. More than anything this information, that provides links among many dimensions of how conservation decisions are made, is the real benefit of the body of work that we

produced through the Great Lakes CEAP project. The information makes us face, rather than ignore, those tough decision. Should we work only in watersheds where we can achieve conditions where the biological community will no longer be limited or where we can most improve conditions? Depending on your answer to this question our analyses would tell you to either that the Pigeon-Pinnebog watershed should be the top priority of our four focal watersheds or you should not work there at all.

Another important question we must confront is; Should conservation action and related funding goals be driven by watershed or more detailed subwatershed cost-benefit analyses? The results of our cost-benefit analyses clearly show how important downscaling is because there is not a simple additive mathematical relationship between the costs to achieve unlimiting conditions for a larger watershed and the cost to achieve those same conditions for all tributary streams in that watershed. The question really stream specific due to the unique natural and human disturbance conditions in the watershed, which demonstrates why our approach and in particular the downscaling of the SWAT model is so important. If we had not downscaled our results to the subwatershed scale the results for the outlets might be interpreted that water quality in all streams of the Cass, Rifle and Shiawassee could be improved to the point that row-crop agriculture was no longer limiting the fish community, for “only” \$7.7M. Yet, the more detailed subwatershed cost-benefit analyses predict fish communities would still be limited in many of the subwatersheds under the 50% conservation scenario, which has an estimated overall installation cost of around \$44M. Our results suggest that in some cases, 100% coverage of traditional conservation practices still might not achieve unlimiting conditions. And given variability in landowner interest in conservation practices, we know that 100% implementation is generally unrealistic (Knowler and Bradshaw 2007, Prokopy et al. 2008). Regardless, difficult decisions will be required at local, regional, and national levels.

Probably the most sobering results of this project were from a comparative assessment of estimated restoration costs to our current level of investment in restoration through the U.S. Farm Bill. We recognize that the Farm Bill is not the only source of restoration funds, but it is the largest funding source for restoration on agricultural lands. Under the 2008 Farm Bill the state of Michigan received a total of \$40,788,221. The total cost of our 50% conservation scenarios for our four watersheds is over \$44M and even though many of the fish communities are predicted to no longer be limited by nonpoint source impacts from row-crop agriculture, several streams still would be limited particularly in the Pigeon-Pinnebog. So, if we set our goals according to those used in this report then our four watersheds, which represent a small fraction of the total acreage of row-crop, would use up most or all of the conservation program funds available to Michigan. So, with those goals the scope of the problem, in terms of costs related to historical practice implementation, is predicted to be significantly greater than the resources that were available to Michigan under the 2008 Farm Bill. Through strategic placement practices we can reduce these costs by ~25% or more in some instances (Legge et al 2013). Yet, even with such savings to achieve these ecological goals across Michigan or all agricultural lands will force the conservation and agricultural community, legislators, businesses, and the public to make some hard decisions to a) significantly increase the conservation provisions of the Farm Bill, b) think “outside the box” to develop new conservation practices or strategies, c) lower our ecological goals, or d) a combination of all three.

Once example of new conservation strategy could be to utilize the results of our analyses to guide restoration efforts from a reserve design perspective (Margules and Pressey 2000, Groves et al.

2003) to strategically conserve lower mainstems of the rivers and key headwater systems. Using this perspective conservation practices could be strategically concentrated at higher rates in specific subwatersheds where unlimiting conditions could be attained while at the same time creating similar conditions for the mainstems. Other factors would also need to be considered, such as the willingness of farmers to work cooperatively at watershed scales to adopt practices and hydrologic connectivity between mainstem and tributary reaches to better benefit fish and other aquatic organisms (Schlosser 1991, Fausch et al. 2002).

Watershed managers, conservation district technicians and even grassroots volunteer groups are often the local water quality advocates that are making major conservation management decisions with very little data and little understanding about how on-the-ground efforts will or can effect ecological resources at larger scales. Yet, improvements in ecological resources are usually the very goals, however implicitly stated, of these very conservation programs. The unique modeling approach developed in the Great Lakes CEAP project has managed to consolidate, analyze and present an enormous amount of data in a way that these key decision makers can use in the field to start making better management decisions today. The Cass River Implementation Pilot Project and our other ongoing efforts with local partners in the Saginaw Bay watershed showcase how the results from our project can immediately influence targeting, outreach and implementation decisions and expectations. One of the most important and gratifying aspects of our project has been the help we received from local partners during the project and also their rapid acceptance and use of the results to guide their conservation efforts. This more than anything has been a testament to the importance of answering the ever present “How much is enough?” question in way that forces to answer several difficult questions related to setting related sets of realistic performance goals and strategies for achieving them.

However, the products of our project can be used by a much broader array of stakeholders than those we have highlighted in this report. For instance, state regulatory agencies could use the model to help determine where grant funding would best be spent to offer the highest return on investment, where future biological monitoring should take place or where future watershed management or fisheries management plans should be developed. Local land conservancies could use the model to determine if their projects would best assist local efforts to preserve land and local habitat in areas of the watershed that are currently not limiting or areas where fish community health is poor. Local fish interest groups like Trout Unlimited may be able to use the data to determine where fish health may be at risk and institute additional monitoring to help gather data, supplement the model recommendations, establish related baselines from field data, and help prepare for future climate change impacts or steer their funding towards implementation projects.

There are several important caveats to interpreting the results presented in this and our Phase 1 report. First, this whole body of work was done through the perspective of a resource management specialist whose job it is to minimize or eliminate nonpoint sources impacts to freshwater fish communities that result from row-crop agriculture. To stay focused on this perspective we generically based our overall approach on the approach a medical specialist would use to assess and treat a patient’s health. They first identify inherent natural differences among patients to develop customized expectations for various health indicators, which is what we did by identifying any differences in the inherent natural ceilings for our fish community metrics associated with watershed physiography. A good medical specialist will broadly assess health and life style

indicators to identify problems and likely causes. If a problem is identified that is likely caused by something they cannot treat, then they will send you to another appropriate specialist. This is what we did by identifying streams that were likely more limited by non-target disturbances such as impervious surfaces. For those problems that the specialist was trained to treat they will often assess their relative degree of severity to your health and develop a treatment plan for successively addressing these problems. We mimicked this assessment process by first identifying those streams where nonpoint source water quality and flow impairments, most likely caused by row-crop agriculture, were limiting the fish community and then assessing the individual and collective improvements to these variables under future conservation scenarios. From this analogy we hope to make it clear that when we state or show, like in Figures 9 or 16, that a particular stream or subwatershed is no longer limiting that that does not mean you would have a healthy fish community and consistently have fish community samples with IBI scores near or at 100. Those statements and figures should be interpreted as the fish community is likely no longer limited by impairments to those particular water quality and flow parameters caused by nonpoint source impacts from row-crop agriculture. Again, there are many other disturbances out there and it is highly unlikely that you would ever see an IBI score of 100 in a channelized stream segment or below a dam or below a point source effluent (Rankin et al. 1999; Robertson et al. 2006; Hambrook-Berkman et al. 2010). Even though we did assess some non-target disturbances we did not assess them all.

Another important caveat is that we used an upper maximum value of 100 for IBI to define when the fish community is no longer limited conditions, which is a high threshold. In fact, since an IBI score of 85 or higher is generally considered excellent (Wang et al. 2006) and scores above 70 are often considered good (Lyons 2006), our results could be reinterpreted using these lower thresholds. Under these lower threshold values, most subwatersheds would be considered no longer limiting under the 50% conservation practice scenario, including some Pigeon-Pinnebog watersheds. Such lower thresholds might be warranted, but that is up to society to decide. However, it is critical to point out threshold analyses are an entirely different statistical method than the reference stream analyses used to establish most IBI criteria and so they are not directly comparable. Also, we caution against lowering thresholds since water quality is just one of many potentially limiting variables, and many conservation problems result from cumulative, interactive impacts across a broad spectrum of factors (Gosselink et al. 1990, Childers and Gosselink 1990, Bolstad and Swank 1997, Schindler 2001). For example, local instream habitat is well known to play a major role in determining biological condition (Rankin et al. 1999; Stewart et al. 2001). Furthermore, the predicted ecological benefits of our conservation scenarios under projected future climate conditions suggest even greater investments will be needed to achieve water quality conditions that do not limit the fish communities. For these reasons we strongly encourage using our more conservative thresholds for setting ecological and related performance goals.

The last important caveat is that our body of work only pertains to riverine ecosystems and associated fish communities. Consequently, any recommended conservation action goals that are generated by our projected improvements in water quality and associated benefits to the fish community could be grossly inadequate for addressing other problems like harmful algal blooms (HABs) or vice versa. HABs and related socioeconomic impacts like beach closings and reduced charter fishing revenue are critical issues in many Great Lakes bays (Murray et al. 2010). Altered hydrology and increased nutrient inputs associated with agriculture have been identified as one

contributor to this problem which has been exacerbated by the introduced dreissenid quagga and zebra mussels (Hecky et al. 2004). Efforts are underway to establish nutrient load goals for several bays in the Great Lakes, like Western Lake Erie and Maumee Bay (GLCPRTF 2012). This brings up a critical point in that we have to continually strive for full-cost and benefit accounting of conservation. Many things that society values are tied to sustainable agricultural production. Most conservation practices simultaneously provide multiple ecological benefits (Comer et al. 2007) and where you prioritize to implement practices and in what amount they are needed will in most instances be different among those ecological endpoints. For instance, if the primary goal was reducing HABs in Great Lakes bays the focus might be on those watersheds delivering the highest nutrient loads to the bays, yet as we witnessed in our project those watersheds might not be the highest priority for restoring riverine fish communities.

During Phase 1 of the Great Lakes CEAP project we identified several ways to improve the downscaled SWAT modeling and also the ecological modeling for identifying thresholds and ceilings (Sowa et al. 2011). Fortunately, through our work on Objective 2 in Phase 2 of this project we were able develop and launch, through the support of NRCS CEAP, the Western Lake Erie Basin (WLEB) CEAP project, which is addressing almost all of these recommended improvements. Furthermore, the WLEB CEAP project serves another, equally important, purpose to foster the formal integration of the Wildlife and Cropland components of CEAP, which is occurring as a result of the unique modeling and assessment approach developed by the Great Lakes CEAP project. It is our hope that the combined results and benefits of the Great Lakes and WLEB CEAP projects will lead to both the desired operational integration of the Wildlife and Cropland components of CEAP and the continued expansion and use of our approach to other geographies. As our work with partners show the conservation and agricultural communities desire having the ability to establish realistic sets of related performance goals that are ecologically based and provide a foundation for strategic, outcome-based, conservation.

Conclusion

Conservation action and funding goals for restoring fish and wildlife habitat in agricultural landscapes should be established based on what is needed to achieve a desired set of ecological conditions. However, those ecological goals must be realistic relative to available resources. These reciprocal questions can only be answered through the information provided by the types of cost-benefit analyses we were able to perform in the Great Lakes CEAP project. Yet, even with this information in hand there are no easy answers but it does make us face, rather than ignore, those tough decisions that balance what is ecologically meaningful with what is economically feasible. Still, as the positive feedback from our partners clearly shows, the conservation and agricultural communities desire having this information so they can make these tough decisions. We believe our approach can and should be expanded to other regions of the United States, but should also be continually improved just as we are now doing through the WLEB CEAP project. We also believe our approach should be expanded to additional ecological and socioeconomic endpoints in order move us towards a more comprehensive accounting of the costs and many benefits of conservation practices on agricultural lands. Finally, the results of this study indicate that our current level of investment in conservation of agricultural lands for the restoration of riverine ecosystems is not commensurate with the scope (cost) of the problem. We must face this reality and substantially increase our investments, fundamentally change our strategies, lower our ecological expectations, or a combination of those three.

LITERATURE CITED

Allan, J.D. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. *Annual Review of Ecology and Systematics* 35:257–84.

Bolstad, P.V. and W.T. Swank. 1997. Cumulative impacts of landuse on water quality in a Southern Appalachian watershed. *Journal of the American Water Resources Association*. 33:519-533.

Brenden, T.O., L. Wang, and Z. Su. 2008. Quantitative identification of disturbance thresholds in support of aquatic resource management 42:821-832.

Brenden, T.O., L. Wang, and P. W. Seelbach. 2008. A river valley segment classification of Michigan streams based on fish and physical attributes. *Transactions of the North American Fisheries Society* 137: 1621-1636.

Burger Jr. L.W., D. McKenzie, R. Thackston, S. J. Demaso. 2006. The Role of Farm Policy in Achieving Large-Scale Conservation: Bobwhite and Buffers. *Wildlife Society Bulletin* 34:986-993

Childers, D.L. and J.G. Gosselink. 1990. Assessment of cumulative impacts to water quality in a forested wetland landscape. *Journal of Environmental Quality* 19:455-464.

Cuffney TF, Meador MR, Porter SD, Gurtz ME. 2000. Responses of physical, chemical, and biological indicators of water quality to a gradient of agricultural land use in the Yakima River Basin, Washington. *Environmental Monitoring and Assessment* 64:259–70.

Dodds, W.K., W.H. Clements, K. Gido, R.H. Hilderbrand, and R.S. King. 2010. Thresholds, breakpoints, and nonlinearity in freshwater as related to management. *Journal of the North American Benthological Society* 29:988-997.

Comer, P., D. Diamond, S. P. Sowa, K. Goodin, D. Purcell, D. Butler, E. Cook, C. Hamilton, G. Hammerson, L. Master, T. Nigh, M. Ormes, D. True, and B. White. 2007. Using NatureServe Information to Assess Farm Bill Practice Effects on At-risk Species and Habitats. Report to the USDA Natural Resource Conservation Service, Washington DC. 53pp. plus appendices

Duriancik, L.F., D. Bucks, J.P. Dobrowolski, T. Drewes, S.D. Eckles, L. Jolley, R.L. Kellogg, D. Lund, J.R. Makuch, M.P. O'Neill, C.A. Rewa, M.R. Walbridge, R. Parry, and M.A. Weltz. 2008. The first five years of the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation* 63(6):185A-197A.

Einheuser, M. 2011. Exploring relationships between in-stream conditions and ecological health while assessing landuse and climate scenarios. MS Thesis. Department of Biosystems and Agricultural Engineering, Michigan State University. 187 pages.

Einheuser, M. , A. Pouyan Nejadhashemi, L. Wang, and S. Sowa. *In Press*. Exploring relationships between in-stream conditions and ecological health while assessing land-use and climate scenarios. *Science of the Total Environment*.

Einheuser, M. D., A. Pouyan Nejadhashemi, S. P. Sowa, L. Wang, Y. A. Hamaamin and S. A. Woznicki. 2012. Modeling the effects of conservation practices on stream health. *Science of the Total Environment*. 435/436: 380-391.

Fausch K.D., C.E. Torgersen, C.V. Baxter, H.W. Li. 2002. Landscapes to riverscapes: bridging the gap between research and conservation of stream fishes. *BioScience* 52:483–98.

Federal Interagency Stream Restoration Working Group (FISRWG). August 2001. Stream corridor restoration – principles, processes and practices, adopted as Part 653 of the National Engineering Handbook, USDA-Natural Resources Conservation Service. Available from: http://www.nrcs.usda.gov/technical/stream_restoration/.

Fore, J.D. 2012. Remediating effects of human threats on lotic fish assemblages within the Missouri River Basin: How effective are conservation practices? A Dissertation presented to the faculty of the Graduate School of the University of Missouri-Columbia.

Franks Taylor, R., A. Derosier, K. Dinse, P. Doran, D. Ewert, K. Hall, M. Herbert, M. Khoury, D. Krause, A. Lapenna, G. Mayne, D. Pearsall, J. Read, B. Schroeder. 2010. The Sweetwater Sea: An International Biodiversity Conservation Strategy for Lake Huron – Technical Report. A joint publication of The Nature Conservancy, Environment Canada, Ontario Ministry of Natural Resources Michigan Department of Natural Resources and Environment, Michigan Natural Features Inventory Michigan Sea Grant, and The Nature Conservancy of Canada. 264 pp. with Appendices.

Frey, J.W., A.H. Bell, J.A. Hambrook-Berkman, and D.L. Lorenz. 2011. Assessment of nutrient enrichment by use of algal-, invertebrate-, and fish-community attributes in wadeable streams in ecoregions surrounding the Great Lakes. U.S. Geological Survey Scientific Investigations Report 2011–5009, 49 p.

Gosselink, J. G., G. P. Shaffer, L. C. Lee, D. M. Burdick, D. L. Childers, N. C. Leibowitz, S. C. Hamilton, R. Boumans, D. Cushman, S. Fields, M. Koch, and J. M. Visser, 1990. Landscape Conservation in a Forested Wetland Watershed: Can We Manage Cumulative Impacts? *BioScience* 40:588-600.

Gray,, R.L. and B.M. Teels. 2006. Wildlife and fish conservation through the Farm Bill. *Wildlife Society Bulletin* 34:906-913.

Great Lakes Commission Phosphorus Reduction Task Force (GLCPRTF). 2012. Priorities for reducing phosphorus loadings and abating algal blooms in the Great Lakes – St. Lawrence River Basin: Opportunities and challenges for improving Great Lakes aquatic ecosystems. A report of the Phosphorus Reduction Task Force to the Great Lakes Commission. Ann Arbor, MI. 40 pp.

Groves, C.R., M.W. Beck, J.V. Higgins, E.C. Saxon. 2003. Drafting a conservation blueprint: A practitioner's guide to planning for biodiversity. Washington (DC): Island Press. 457 p.

- Hambrook-Berkman, J.A., B.C. Scudder, M.A. Lutz, and M.A. Harris. 2010. Evaluation of aquatic biota in relation to environmental characteristics measures at multiple scales in agricultural streams of the Midwest: 1993-2004. US Geological Survey Scientific Investigations Report, 2010-5051, 24p.
- He, C. and C. DeMarchi, 2010. Modeling Spatial Distributions of Point and Nonpoint Source Pollution Loadings in the Great Lakes Watersheds. *International Journal of Environmental Science and Engineering*, 2:24-30.
- Heard L. P, A. W. Allen, L. B. Best, S. J. Brady, W. Burger Jr., A. J. Esser, E. Hackett, D. D. Johnson, R. L. Pederson, R. E. Reynolds, C. Rewa, M. Ryan, R. Molleur, and P. Buck. 2000. A comprehensive review of Farm Bill contributions to wildlife conservation, 1985 - 2000. Technical Report WHMI-2000, U.S.Department of Agriculture, Natural Resources Conservation Service, Madison, Mississippi, USA
- Hecky, R E, H. Smith, D. R. Barton, S. J. Guildford, W. D. Taylor, M. N. Charlton, T. Howell. 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 61:1285-1293
- Heiskary S, and H. Markus. 2003. Establishing relationships among instream nutrient concentrations, phytoplankton and periphyton abundance and composition, fish and macroinvertebrate indices, and biochemical oxygen demand in Minnesota USA rivers. Minnesota Pollution Control Agency, Environmental Outcomes Division, St. Paul, MN
- Higgins, J. V., M. T. Bryer, M. L. Khoury, and T. W. Fitzhugh. 2005. A Freshwater Classification Approach for Biodiversity Conservation Planning. *Conservation Biology* 19(2): 432–445.
- Johnson, L.B., C. Richards, G.E. Host and J.W. Arthur. 1997. Landscape influences on water chemistry in Midwestern stream ecosystems. *Freshwater Biology* 37:193-208.
- Karr JR. 1981. Assessment of biological integrity using fish communities. *Fisheries* 6:21–27
- Knowler, D., and B. Bradshaw. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32:25-48.
- Lammert, M., and J. D. Allan. 1999. Assessing biotic integrity of streams: effects of scale in measuring the influence of land use/cover and habitat structure on fish and macroinvertebrates. *Environmental Management* 23:257-270.
- Legge, J.T., P.J. Doran, M.E. Herbert, J. Asher, G. O'Neil, S. Mysorekar, S. Sowa, and K. Hall. 2013. From model outputs to conservation action: Prioritizing locations for implementing agricultural best management practices in a Midwestern watershed. *Journal of Soil and Water Conservation* 68:22-33.

- Liskauskas, A., J. Johnson, M. McKay, T. Gorenflo, A. Woldt, and J. Bredin. 2007. Environmental Objectives for Lake Huron. A Report of the Lake Huron Technical Committee, Great Lakes Fishery Commission.
- Lyons, J. 1992. Using the index of biotic integrity (IBI) to measure environmental quality in warmwater streams of Wisconsin. General Technical Report NC-149, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minn.
- Lyons, J., L. Wang, and T.D. Simonson. 1996. Development and validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin. *North American Journal of Fisheries Management* 16:231-256.
- Magnuson, J.J., Webster, K.E., Assel, R.A., Bowser, C.J., Dillon, P.J., Eaton, J.G., Evans, H.E., Fee, E.J., Hall, R.I., Mortsch, L.D., Schindler, D.W. & Quinn, F.H. 1997. Potential effects of climate changes on aquatic systems: Laurentian Great Lakes and Precambrian Shield Region. *Hydrological Processes* 11: 825–871.
- Maresch, W., M.R. Walbridge, and D. Kugler. 2008. Enhancing conservation on agricultural landscapes: A new direction for the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation* 63(6):198A–203A.
- Margules C.R. And R.L. Pressey. 2000. Systematic conservation planning. *Nature* 405: 243–253.
- Mausbach, M.J., and A.R. Dedrick. 2004. The length we go: Measuring environmental benefits of conservation practices. *Journal of Soil and Water Conservation* 59:96A-103A.
- Meals, D. W., S. A. Dressingb and T. E. Davenport. 2010. Lag Time in Water Quality Response to Best Management Practices: A Review. *Journal of Environmental Quality* Vol. 39 No. 1, p. 85-96
- Miltner, R.J. 2010. A method and rationale for deriving nutrient criteria for small rivers and streams in Ohio. *Environmental Management* 45:842-855.
- Murray, C, B. Sohngen, and L. Pendleton. 2010. Valuing water quality advisories and beach amenities in the Great Lakes. *Water Resources Research* 37(10): 2583-2590.
- Prokopy, L.S., K. Floress, D. Klotthor-Weinkauff and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. *Journal of Soil and Water Conservation* 63:300-311.
- Rankin, E., B. Miltner, C. Yoder and D. Mishne (1999). Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams. Columbus, OH, Ohio Environmental Protection Agency.
- Reimer A. P., D. K. Weinkauff, and L. S. Prokopy . 2012. The influence of perceptions of practice characteristics: An examination of agricultural best management practice adoption in two Indiana watersheds. *Journal of Rural Studies* 28:118-128

Richards, C., R. Haro, L. Johnson, and G. Host. 2003. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. *Freshwater Biology* 37:219-230.

Richter B.D., D.P. Braun, M.A. Mendelson, L.L. Master. 1997. Threats to imperiled freshwater fauna. *Conservation Biology* 11:1081-1093.

Robertson, D. M., D. J. Graczyk, P. J. Garrison, L. Wang, G. LaLiberte, and R. Bannerman. 2006. Nutrient concentrations and their relations to the biotic integrity of wadeable streams in Wisconsin. U.S. Geological Survey Professional Paper 1722. U.S. Geological Survey, Reston, Virginia, USA.

Roth NE, J.D. Allan, D.L. Erickson. 1996. Landscape influences on stream biotic integrity assessed at multiple spatial scales. *Landscape Ecology* 11:141–56

Schindler, D.W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. *Canadian Journal of Fisheries and Aquatic Sciences* 58:18-29.

Schlösser IJ. 1991. Stream fish ecology: A landscape perspective. *BioScience* 41: 704–712.

SWCS. 2006. Final Report from the Blue Ribbon Panel Conducting an External Review of the U.S. Department of Agriculture Conservation Effects Assessment Project. Ankeny, IA: Soil and Water Conservation Society.

http://www.swcs.org/en/publications/blue_ribbon_panel_conducting_a_review_of_ceap

Sowa, S. P., M. Herbert, L. Cole, S. Mysorekar, J. Legge, T. Bowe, A. Nejadhashemi, M. Einheuser, and L. Wang. 2011. Assessing benefits of conservation practices to the biological integrity of agricultural streams in MI and WI. Final Report submitted to NRCS Conservation Effects Assessment Project. 56 pp.

Stewart, J.S., L. Wang, J. Lyons, J.A. Horwath, R. Bannerman. 2001. Influences of watershed, riparian-corridor and reach-scale characteristics on aquatic biota in agricultural watersheds. *Journal of the American Water Resources Association* 37:1475-1487.

The Nature Conservancy (TNC). 2000. Toward a New Conservation Vision for the Great Lakes Region: A Second Iteration. The Nature Conservancy, Great Lakes Program, Chicago, Illinois.

The Nature Conservancy (TNC). 2001. Aquatic ecoregional planning in the U.S. Portion of the Great Lakes Watershed. The Nature Conservancy, Great Lakes Program, Chicago, Illinois.

USDA 2010. National Conservation Practice (NCP) database. USDA Natural Resources Conservation Service. Washington, DC.

Wang L, J. Lyons, P. Kanehl, R. Gatti. 1997. Influences of Watershed Land Use on Habitat Quality and Biotic Integrity in Wisconsin Streams. *Fisheries* 22:6-12

Wang, L., J. Lyons, and P. Kanehl. 2006. Responses of habitat and fish to agricultural best management practices in a warmwater stream. *Journal of the American Water Resources Association* 42: 1047-1062.

Wang, L., D.M. Robertson, and P.J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. *Environmental Management* 39:194-212.

Waters TF. 1995. *Sediment in Streams*. American Fisheries Society, Bethesda, MD

Weigel, B.M. and D.M. Robertson. 2007. Identifying biotic integrity and water chemistry relations in nonwadeable rivers of Wisconsin toward the development of nutrient criteria. *Environmental Management* 40:691-708.

Westra, J.V., J.K. H. Zimmerman, and B. Vondracek, 2005. Bioeconomic analysis of selected conservation practices on soil erosion and freshwater fisheries. *Journal of the American Water Resources Association* 41:309-322.